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U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY.

CEREAL RUSTS OF THE UNITED STATES:

A PHYSIOLOGICAL INVESTIGATION.

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U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY,
Washington, D. C., May 31, 1899.

SIR: I have the honor to transmit herewith a report on the cereal usts of the United States, prepared by Mr. Mark Alfred Carleton, of his Division. Mr. Carleton has been engaged in an investigation of he diseases of cereals for several years and this report contains, in art, the results of the work. The several species of rusts affecting ereals in the United States are fully described, and the distribution of hese rusts is given, together with a detailed statement of the results f extensive observations and experiments to determine the rust resistnce of numerous varieties of wheat and oats. The life history of the usts themselves has been very fully studied and the facts obtained rom this work throw important light on problems connected with the reeding of rust-resistant varieties. In view of the wide distribution nd the destructiveness of the rusts and the value of the results btained, I respectfully recommend that the report be published as Bulletin No. 16 of this Division.

Respectfully,

B. T. GALLOWAY,
Chief of Division.

Hon. JAMES WILSON,
Secretary of Agriculture.

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CEREAL RUSTS OF THE UNITED STATES: A PHYSIOLOGICAL INVESTIGATION.

INTRODUCTION.

The investigator of grain rusts learns three important facts at the beginning of his work: (1) That these rusts are more or less distributed over all parts of the world where cereals are grown, (2) that the average annual losses they cause are very much greater than is generally supposed, and (3) that as yet little is known regarding their ontogenetic relations to each other and to their host plants. In view of the importance of rusts from a botanical standpoint, it is rather surprising that so little attention has been given to their study. In only two of the principal cereal-growing countries—that is, Australia and the United States—have any investigations of cereal rusts been made, and even in Australia, through the investigation of rust resistance, the matter has drifted into a study of the wheat plant itself rather than of the rusts that affect it. In the important cereal regions of Russia, India, and Argentina practically nothing is known about these rusts.

The only studies of the physiological relationships of the grain rusts outside of the writer's, most of which are reported in this bulletin, are those by Dr. Jakob Eriksson, of Sweden, whose researches will be described further on. Several investigations, relating almost wholly to the application of fungicides and the wintering of the parasite, have been made in this country. The most important are those reported by Bolley (6–10),[1] Kellerman and Swingle (41), Pammel (54, 56), Galloway (34), and Hitchcock and Carleton (38, 39).

A brief review of the work on grain rusts so far carried on shows that three distinct phases of the subject have been investigated: (1) The value of fungicides in preventing or checking rust, (2) rust-resistant varieties, and (3) the physiology of the rusts. Much of the work of the American writers above named pertains to the first phase. Besides the experimental work with the common fungicides, special attention was given to the preparation and application of new ones, particularly in the work in charge of the Department (34, Jour. Myc., pp. 199–203). In these trials the seed and soil were also treated with various compounds. The results of these various experiments showed that although

[1] For explanation of this and similar references in this bulletin, see corresponding numbers in bibliography, pp. 70–73.

Bordeaux mixture, ferric chloride, potassium bichromate, mercuric chlo ride, and perhaps one or two other compounds are quite effective i checking the spread of rust, yet, unless some great improvement i made in the method of applying fungicides, it would be practicall impossible to spray a field of grain, owing to the great trouble in reach ing all portions of the plants, and the difficulty, if not impossibility, o using any suitable kind of spraying apparatus in the field withou destroying much of the grain. Besides, the expense of spraying larg fields is an obstacle.

In Australia[1], as above stated, the careful and widespread attentio given to the wheat-rust problem has resolved itself almost wholly int a study of rust-resistant varieties. McAlpine, Shelton, Pearson, an others have contributed much to the knowledge of rust-resistant varie ties, but most of the work in this line has been done by Dr. N. A. Cobl as vegetable pathologist to the government of New South Wales, an William Farrer, a private breeder of rust-resistant varieties of wheat An important concomitant result of the work in Australia is that th country now has wheat varieties that are vigorous, true to name, an of exceptional quality for the particular region in which they are grown

Aside from the series of experiments reported in this bulletin, n systematic study of rust resistance has been made in this country though from time to time observations in this line have been recorde by experiment station workers. Bolley (7, pp. 15, 16) refers to suc observations made as far back as 1889, and farmers have long know that occasionally certain varieties of cereals are more exempt fron rust than others. But in all such investigations as just mentioned th study of the rust itself is practically ignored, and hence much of th experimental work in spraying and selection of varieties is likely to b done blindly or needlessly and lead to unreliable conclusions. Ther would obviously be no necessity for combating a cereal rust ever season if by knowing its life history it could be prevented from gettin a start. Moreover, spraying experiments that prove successful in on season or in some certain locality may be an entire failure another sea son or in another locality, simply because different rusts are bein treated in the different instances. So, also, it has been thoroughl demonstrated, as will be discussed further on, that certain varieties o wheat and oats are capable of the greatest variation in their powers o resisting rust, this resistance varying according to the kind of rust, th locality, and the season.

In the course of investigations reported by Hitchcock and the writer the necessity of studying the physiological relationships of the rust and the manner in which they winter over became more and more evi

[1] The results of the Australian investigations were published in a series of report of intercolonial wheat-rust conferences extending from 1890 to 1896, and also in th Agricultural Gazette of New South Wales and various special reports of differen colonies.

lent.[1] The rusts had to be actually grown, and more diligent field bservations became necessary. Everywhere the utmost confusion xisted as to the distribution of cereal rusts on the different grasses, nd frequently even the particular species occurring on any of the different cereals was only a matter of inference. By way of a beginning n clearing up these problems a series of inoculation experiments with redospores was inaugurated by the writer on September 15, 1893, nd carried on until February 1, 1894, the material used being taken rom outdoors and propagated in the greenhouse during the winter. The results of these inoculations showed that the particular rust forms mployed would not infect any cereal but the one from which they vere taken, except *Uredo graminis* from wheat, which when used upon arley produced one rust spot (39, p. 3). It was also found that a *redo form found common on Kentucky blue grass would not infect* vheat nor oats.[2] The conclusion was then expressed that "these experiments seem to show that the rusts of various cereals are probably hysiological species." At the time this work was done the writer was ot aware that Bolley had made some experiments of the same kind. Bolley, however, reached no conclusion (10, p. 263).

On March 1, 1894, the writer began work for this Department, consequently the inoculation experiments just described were dropped nd were not resumed for nearly two years. In the meantime Eriksson, who in 1890 began experiments in the same line, published numerus articles[3] giving many results corresponding with those above nentioned and with others which have not yet been published. In ome instances, however, the results differ.

Specialized forms of cereal rusts.—The species hitherto known all ver northern Europe under the one name, *Puccinia rubigo-vera* (DC.) Wint., have been separated by Eriksson and Hennings into two disinct species, i. e., *P. glumarum* (Schmidt) Eriks. and Henn. (the "yelow rust)," and *P. dispersa* Eriks. and Henn. (the "brown rust") (30, p. 197, 198, 257, 258). Three rusts, therefore, attack wheat in Sweden, he yellow rust being, it is said, the most common and destructive. So ar as known this yellow rust does not occur in America, but the brown

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[1] Such ideas had already been expressed by the writer in Science, Vol. XIV, p. 63.

[2] On page 4 of the Kansas Agr. Expt. Sta. Bull. No. 46 it is stated that *Uredo raminis* of oats would not infect orchard grass, but subsequent investigations have hown that this grass is a common host for that rust.

[3] Eriksson, Jakob, *Die Getreideroste*, prepared in conjunction with Ernst Hennings nd published originally in Swedish, comprises the details of Eriksson's investigaions from 1890 to 1893. It did not reach America until the summer of 1896. The rincipal results were given in *Die Hauptresultate einer neuen Untersuchung über die Getreideroste* (Zeitschr. f. Pflanzenkrank., 1894, Vol. IV, pp. 66–73, 140–142, 197–203). The first part of this article appeared one month before the results obtained by Hitchcock and the writer were published, but was not seen by them for some ime after. *Ueber die Specialisirung des Parasitismus bei den Getreiderostpilzen* (*Ber. Deutsch. Bot. Ges.*, 1894, Vol. XII, pp. 292–331) gave the results of his further experiments for 1894, and also references to the work of Hitchcock and the writer. Subequent to 1894 Eriksson's researches have been reported in various papers.

rust is probably the same as our *P. rubigo-vera.* These authors also make the rust heretofore called *P. rubigo-vera simplex*, occurring on barley, a distinct species—that is, *P. simplex* (Kcke.) Eriks. and Henn. (30, p. 260). The writer has no reliable information as to the occurrence of this species on barley in this country, but what is possibly the same rust has been found occasionally on native species of Hordeum.

In his inoculation experiments Eriksson also has observed that forms of a certain rust species taken from certain hosts would not infect certain other hosts that are attacked by this same species. This may be true even where the hosts are of the same genus. On the other hand, infections will sometimes take place from the host species of one genus to the species of another genus. To such distinct forms of the same rust species he has given the name *forma specialis.* The form name is taken from the generic name of one of the hosts to which the form is restricted, preceded by the abbreviation f. sp. As there seems to be no good reason why the entire name should not be written as an ordinary trinomial, designating the variety, it will be so written in this bulletin. These forms are, as a rule, as good varieties as those established on morphological grounds by phanerogamic botanists.

Eriksson's researches have led him to conclude that so far as known there are at present ten forms of these cereal rusts in Sweden, that is, three black rusts, *Puccinia graminis secalis* on rye and barley, *P. graminis tritici* on wheat, and *P. graminis avenæ* on oats; three yellow rusts, *P. glumarum secalis* on rye, *P. glumarum tritici* on wheat, and *P. glumarum hordei* on barley; two brown rusts, *P. dispersa secalis* on rye and *P. dispersa tritici* on wheat; one dwarf rust, *P. simplex* on barley; and one crown rust, *P. coronifera* on oats. The writer's inoculation experiments in 1896 and 1897, several thousand in number, which will be described in detail further on, showed that there are now at least six distinct forms of cereal rusts in the United States, and probably a seventh, namely, two orange leaf rusts, *P. rubigo-vera tritici* on wheat and *P. rubigo-vera secalis* on rye; one crown rust, *P. coronata* on oats; three black stem rusts, *P. graminis tritici* on wheat and barley, *P. graminis secalis* on rye, and *P. graminis avenæ* on oats; and one maize rust, *P. sorghi* on maize.

In comparing the Swedish and the American rusts, it should be observed that Eriksson uses for the crown rust the name established by Klebahn (42, pp. 134–136), that is, *P. coronifera.* He justifies this upon the basis of his own (28) and upon Klebahn's experiments, which showed that in northern Europe *P. coronata* Corda is a collective species, of which one section has *Rhamnus cathartica* for its æcidial host and occurs on oats and other grasses, and another section has *R. frangula* for its æcidial host, but does not occur on oats. The former is called *P. coronifera* and the latter is called by the old name *P. coronata.* Each of these newly made species has also its specialized forms or varieties, there being eleven in all. As the writer has not yet deter-

ned the æcidial host of the crown rust of oats for this country,[1] it leemed best to retain, for the present, the old name *P. coronata;* and ile Eriksson and Hennings's division of *P. rubigo-vera* is undoubtedly rect, it seems, nevertheless, preferable to retain this well-known me[2] until it is positively determined whether our species is equivat to *P. dispersa* or is a new one. It has already been stated that *glumarum* and probably *P. simplex* do not occur in this country, and course *P. sorghi* does not occur in Sweden.

Common nomenclature of grain rusts.—The common nomenclature of se rust forms is a complex question. The names above given were ided upon, after much consideration, as being the most accurate and scriptive that could be used. In the case of *P. graminis* and *P. bigo-vera* the names have been given in accordance with the most nmon and striking characteristics of the species. The former, when occurs in abundance, exists principally upon the stems and in the ck stage, while the latter is most strikingly exhibited on the leaves the orange-colored uredo stage. The crown rust, although also an nge leaf rust, can not be spoken of as such, as it would thus be conted with the orange leaf rust of wheat, which is a different species. course, there need be no confusion in the case of the name of the ize rust, it being the only one on maize.[3]

The Department's work on grain rusts.—With a view to thoroughly estigating the cereal rust question, this Division in the spring of 2 sent to crop reporters in the principal wheat-growing States a cirar requesting information as to the distribution and abundance of different rusts, the damage caused by them, etc. Owing to the ss of other work, however, nothing further was done in this line, cept the spraying experiments in 1892 and 1893, until the writer took rge of the work in the spring of 1894. A circular similar to the ove was then prepared and sent to growers in all States where wheat l oats are grown to any extent, the information requested to be sed on observations made during the season of 1894. The following le gives a combined summary of the answers received to the two sets

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[1] Since the above was written a series of inoculation experiments have shown her conclusively that *Rhamnus lanceolata* acts as an æcidial host of the crown rust his country.

[2] The writer has recently had an opportunity to make personal observations on rusts of wheat in northern Europe—that is, from England to Sweden and southrd to southern Germany—and not only found these two to be very distinct, but also nd that *P. glumarum* was far more common and injurious everywhere during the son of 1898. It seems strange that the two species should have been confounded so long a time. However, there appear to be very good reasons for still retaining name *P. rubigo-vera* for the species called *P. dispersa* by Eriksson and Hennings, here is little doubt that it is the same as the one so well known under the former ne in all other countries where rusts have been studied.

[3] The fact that Eriksson called *P. dispersa* brown rust—and, judging from his specins, he seems correct—is the only reason for doubting that *P. rubigo-vera* of this counis equivalent to it, as our species is certainly orange color in the uredo stage. uredo of the black stem rust would be more properly called brown.

of circulars. North Carolina and Georgia, though not important a wheat States, are included in the table to show the conditions respectin rust in such latitudes.

TABLE 1.—*Summary of reports on the cereal rusts received in 1892 and 1894 from twenty-three States.*

States from which reports were received.	Reports on wheat—		Per cent of damage.[1]	Part of plant chiefly affected by rust.			Reports on oats—		Part of plan chiefly affecte by rust.		
	Injured by rust.	Free from rust.		Stems.	Leaves.	Both.	Injured by rust.	Free from rust.	Stems.	Leaves.	Both.
New York	9	43	23 (2)	1	1	2	27	12	1	13	
Pennsylvania	7	61	30 (20)	1	4	1	53	11	2	9	
Maryland[2]	1	7	17 (2)	......	4	....	4	....	......	3	
North Carolina[2]	6	4	31 (7)	......	7	2	1	4	......	3	....
Ohio	27	73	20 (35)	3	6	4	63	28	1	11	
Michigan	27	54	19 (35)	1	4	10	29	26	......	8	
Indiana	47	87	24 (44)	4	13	2	72	44	1	10	
Wisconsin	32	35	25 (30)	1	2	1	83	21	1	4	
Illinois	34	90	26 (49)	......	14	3	69	22	......	2	....
Kentucky	43	22	40 (52)	1	8	6	40	19	......	4	
Tennessee[2]	8	2	....	1	5	....	....	7	......	1	
Georgia[2]	18	2	25 (10)	......	16	4	1	11	......	4	
Minnesota[2]	6	12	....	......	2	....	4	12	......	4	
Iowa	27	23	46 (16)	......	2	2	80	16	2	3	
Missouri	38	48	26 (52)	1	8	1	46	23	......	5	
North Dakota	7	20	11 (10)	......	......	1	21	5	1	2	
South Dakota	12	43	21 (10)	1	1	2	20	10	......	1	
Nebraska	30	77	28 (37)	......	1	2	67	32	1	5	
Kansas	31	105	25 (38)	1	4	....	70	50	1	7	
Texas[2]	4	10	12 (1)	......	3	5	3	6	1	2	
Washington[2]	......	9	....	......	......	....	....	3	......	......	....
Oregon[2]	1	4	....	......	1	....	....	3	......	......	....
California	3	15	46 (3)	1	......	1	2	10	......	3	

States from which reports were received.	Varieties of wheat free from rust.[2]	Varieties of wheat liable to rust.	Wheat mos affected.	
			Early.	Lat
New York	Clawson (3), bearded varieties (2).	Clawson (3), white varieties (2)	4	[illegible]
Pennsylvania	Fultz (13), Red Lancaster (6)	Late varieties (5), bald varieties (3).	....	[illegible]
Maryland[2]	Fulcaster (2)	Fultz (2)	....	
North Carolina[2]	Fulcaster (3), bearded varieties (1).	Ford (1), May (1)	2	
Ohio	Early varieties (12), Fultz (9)	Late varieties (8), Clawson (7)	5	[illegible]
Michigan	Clawson (12), Fultz (7)	Clawson (14), Mediterranean (4).	3	[illegible]
Indiana	Fultz (27), early varieties (14)	Late varieties (20), bald varieties (9).	1	[illegible]
Wisconsin	Fultz (3), hard varieties (3)	Soft varieties (2), Fultz (2)	2	[illegible]
Illinois	Fultz (19), bearded varieties (10).	Fultz (10), bald varieties (6)	4	[illegible]
Kentucky	Fultz (10), bearded varieties (9).	Bald varieties (8), white varieties (6).	5	[illegible]
Tennessee[2]	Rice wheat (2), Missouri Red (1)	Bald varieties (2), soft varieties (1).	1	
Georgia[2]	Blue Stem (3), Dallas (3)	Walker (1), Moore (1)	....	[illegible]
Minnesota[2]	Saskatchewan Fife (1), Blue Stem (1).	Soft varieties (1)	1	
Iowa	Blue Stem (7), early varieties (3).	Bald varieties (3), soft varieties (2).	....	[illegible]
Missouri	Fultz (32), Mediterranean (21)	Walker (7), Fultz (7)	6	[illegible]
North Dakota	Blue Stem (4), hard varieties (3).	Scotch Fife (3), White Russian (2).	5	[illegible]
South Dakota	Blue Stem (14), hard varieties (4)	Soft varieties (5), Lost Nation (3).	1	[illegible]
Nebraska	Velvet Chaff (10), Blue Stem (6).	Bearded varieties (6), Grass (5).	3	[illegible]
Kansas	Turkey (32), Russian Bearded (11).	Soft varieties (15), May (8)	4	[illegible]
Texas[2]	Mediterranean (4), Nicaraguan (1).	Golden Chaff (1), bald varieties (1).	....	
Oregon[2]	....	Red Chaff (1)	1	....
California	Sonora (2), Odessa (2)	White Club (2), White Australian (2).	1	

[1] The figures in parentheses show the number of replies from which the average per cent w calculated.

[2] The report from this State is for 1894 only.

The writer has visited, in some cases at different times, all the important wheat-growing States except Pennsylvania, Washington, regon, and California. The most extended tour was made in 1894, hen all the wheat-growing States of the Great Plains and of the lississippi Valley were visited. However, on account of the drought hich prevailed during that season the conditions were in some respects ıost unfavorable for a study of the rusts. To gain a very accurate nowledge of conditions in the field a personal inspection of cereal istricts for three to five successive years would be necessary; but, evertheless, the observations just referred to, together with the replies om correspondents, have furnished valuable information and have ade the situation much clearer than before.

ENERAL OBSERVATIONS ON CEREAL RUSTS IN DIFFERENT STATES.

New York.—Rust does not seem to be as prevalent in this State as ı some others. Oats is often injured, especially in Erie and Wyoming ounties. Considerable spring wheat is raised, and it is always more isted than fall wheat, as are also late-sown wheat and oats. There considerable stem rust, but to what extent it prevails over the State not definitely known. Some counties in which rust is quite prevaınt are Franklin, St. Lawrence, Cayuga, Schuyler, Wayne, Clinton, reene, and Cattaraugus.

Pennsylvania.—The reports indicate that wheat is not extensively ımaged by rust, but that oats is very commonly injured. It is quite robable, however, that much of the damage attributed to rust is due "oat blight," a supposed bacterial disease occurring in this State, hich gives the crop a yellowish red appearance. Fertilizers are supposed to materially aid the grain to escape rust by causing rapid rowth and early maturity. The rust is always worst in the lowlands. mong the counties in which rust is especially prevalent are Columbia, dams, Berks, Franklin, Northampton, Schuylkill, Forest, Sullivan, ıd Lackawanna. The standard varieties of wheat grown in this tate are Fultz, Lancaster, and Fulcaster.

Maryland.—It is claimed that the application of fertilizers, especially hosphates, has materially decreased the losses from rust in this State recent years. In the experiments conducted by the Department at arrett Park during three seasons there was an abundance of orange af rust on wheat and crown rust on oats, but they did not appear to any particular damage. Black stem rust was not observed. As Pennsylvania, oat blight produces much of the injury commonly scribed to rust. Much oat rust has been reported from Cecil County.

North Carolina.—Wheat is quite commonly injured by rust, but it is ot grown extensively in this State. The orange leaf rust seems to be ıe prevailing species, though as yet it is uncertain whether it is the ıly one present in cases of severe injury. One peculiar fact of interest that early wheat, such as Early May, is often more injured than late

varieties, which is just the reverse of the rule. A probable reason f this is that early wheat is sometimes weakened by frosts or freezes an is thus rendered more liable to rust. In the Atlantic coast States tl wild blackberry rust (*Cæoma nitens*) is extremely abundant, especial in the edges of clearings near fields of wheat—a fact which has giv rise to the erroneous opinion in this State that this rust has son ontogenetic connection with the cereal rusts (53, p. 16). Three counti in which rust is quite prevalent are Randolph, Alexander, and Moo

Ohio.—The black stem rust is occasionally very prevalent in tl State. There is much more injury by rust to oats than to wheat. (account of early ripening, Fultz wheat is less liable to rust than oth varieties. Here, also, fertilizers cause rapid growth and early maturit and act to some extent as preventives of rust. The counties in whi rust is reported to be especially injurious are Clark, Stark, Richlan Fayette, Hancock, Knox, Logan, Guernsey, Crawford, Scioto, Defianc Greene, Medina, Mercer, Meigs, Miami, and Harrison.

Michigan.—In this State wheat is often badly damaged by rust, bu as in all the North Central States, oats suffers still more. Wheat much more liable to rust injury after winterkilling, hence late varieti suffer more than the early varieties. The varieties of wheat most ge erally grown are Clawson and Fultz. Rust rarely occurs in the sand districts. It is apparently most abundant in Antrim, Jackson, Wayn Charlevoix, Cheboygan, Lapeer, Benzie, Alcona, Leelanau, Clinto Shiawassee, Livingston, Washtenaw, Osceola, Midland, Saginaw, ar Ingham counties.

Indiana.—Wheat is much injured and oats is commonly damag in this State by rust. Late varieties are invariably much more liab to rust than the early varieties. Fultz wheat escapes rust, not becau it is rust resistant, but because it ripens early. In some instances tl growing of oats has been abandoned on account of rust. Grain said to be free from rust in the warm, sandy soils. Some claim that is very severe only once in two to five years. Black stem rust is tl most injurious species occurring in this State. The counties in whi the greatest amount of rust is found are Wayne, Vanderburg, Je nings, Pike, Sullivan, Greene, Ohio, Union, Lawrence, Posey, Gibso Clinton, Ripley, Bartholomew, Huntington, Adams, Morgan, Well Clark, Delaware, Miami, Starke, and Johnson.

Wisconsin.—According to nearly half the reports received from th State, wheat is commonly damaged by rust. As in some other State it is believed by many that an application of salt, lime, or ash hastens ripening and makes stiffer and cleaner straw. It is claime by some that White Russian oats possesses a considerable degree rust resistance. Black stem rust constitutes a good proportion of tl cereal rusts. Some of the counties in which there is much rust a Marathon, Pepin, Waukesha, Richland, Ozaukee, Brown, Waupac Adams, Marquette, Dunn, Waushara, Polk, Sauk, Outagamie, Junea

Illinois.—Oats is commonly and often seriously damaged by rust. he damage to wheat is much less, although it, too, often suffers verely. In 1890 and 1891 rust was unusually severe in some locali-es. It is always worst in fields of grain that have winterkilled. The amage is particularly severe once in three to five years. Wheat eems to suffer more in the extreme northern and southern portions of e State than in the central part—due in the southern part probably to e latitude and climate, and in the northern part to the large propor-on of spring wheat grown there, but spring wheat is rapidly losing restige and is not grown so extensively as formerly. Fultz wheat is popular variety throughout the State. In some localities tile drainage said to reduce the amount of rust. Some believe that although earded varieties are less liable to rust on prairie lands, they are more able to it on timber lands, but on what this belief is based the writer oes not know. Some of the counties in which much rust seems to ccur are Hardin, Morgan, Massac, Williamson, Whiteside, Edgar, ekalb, Grundy, Cass, Menard, Cook, Boone, Lee, Carroll, Woodford, tark, Pope, Lawrence, Stephenson, Pulaski, Johnson, and Jersey.

Kentucky.—The reports of correspondents, as well as the writer's bservations, indicate that in this State wheat is very commonly and everely damaged by rust. In other States the complete destruction f the crop occurs occasionally, but in this State this is a common ccurrence. Black stem rust is very common and, as it appears later an the orange leaf rust, the introduction of early-maturing varieties a matter of much importance. Some make a practice of harvesting e grain while in the "dough" stage in order to escape the rust. Oats also extensively injured. Some of the counties where the grain is ost affected are Trigg, Harrison, Metcalfe, Simpson, Jackson, Caldwell, enderson, Nelson, Allen, Garrard, Grayson, Adair, Magoffin, Crit-enden, Fayette, Casey, Calloway, Webster, Christian, Livingston, etcher, Grant, Graves, McLean, Ballard, Muhlenberg, Marshall, lartin, Lawrence, Estill, McCracken, Kenton, Montgomery, Knox, lay, Monroe, Boone, and Ohio.

Tennessee.—The information concerning rust in this State is still quite eager, though the writer has made two trips of observation to different calities. However, the indications are that wheat is rather commonly jured by rust. The stem rust is very severe some years, but seems be less common than in Kentucky. Little injury is done to oats. ice wheat is considered by some to be a rust-resistant variety. Fultz nd Fulcaster are favorite varieties in some localities. Stem rust ecomes abundant from May 20 to June 1. Greene County seems to ave considerable rust.

Georgia.—Very little wheat is raised in Georgia, but usually what is rown is badly injured by rust. Leaf rust is the species most prevalent, ut frequently the grain is not severely injured until the stem rust ppears. In this State, as in all the Gulf States, oats is seldom injured

ʾroof. Scarcely a county in the State is free from rust, but it appears o be most abundant in Lincoln, Jones, Milton, Catoosa, Hart, Ran- :olph, Bartow, Henry, Marion, and Sumter counties.

Minnesota.—Not much information is at hand concerning rust in this ltate, but it is known that in certain years both wheat and oats are reatly injured. The Fifes and the Blue Stem are the standard varie- ies of wheat generally grown. White Russian oats is said by some to e rust resistant. Reports of rust have been received especially from tearns, Fillmore, Renville, Ottertail, and Watonwan counties.

Iowa.—So great has been the damage from rust in this State that in ome parts wheat growing has been gradually abandoned principally om this cause. In Buena Vista County it is reported that there has een an average annual loss of 10 per cent of the crop during the past venty-two years. This severity of the rusts is doubtless due to the ractice of spring sowing, so common in the State. The great desid- ratum for Iowa in the way of cereals is a good, hardy wheat like the ard red wheats from south central Russia, as the Ghirkas, Crimean, x, etc. The amount of oats sown in the State as compared with heat is becoming quite large, but rust often destroys this crop also. ; is always the black stem rust that is particularly injurious. Rust is retty evenly distributed over the State, but it is probably particularly bundant in Fremont, Buena Vista, Des Moines, Dallas, Clay, Butler, rawford, Cerro Gordo, Appanoose, Buchanan, Cedar, Cherokee, reene, Franklin, Emmet, Allamakee, and Plymouth counties.

Missouri.—There is considerable rust in this State, but not much is nown concerning the relative proportions of leaf rust and stem rust cases of great injury. Mediterranean wheat is considered to be ither rust resistant. Oats is often much injured. Rust seems espe- ally common in Christian, Crawford, Bollinger, Carroll, Atchison, on, Oregon, Dent, Dekalb, Franklin, Carter, Hickory, Livingston, lercer, Sullivan, Daviess, Madison, Grundy, Nodaway, Gasconade, inn, Jefferson, and Perry counties.

North Dakota.—Wheat does not seem to be commonly damaged in is State, although leaf rust is always present and is sometimes oundant. Oats, however, is often injured. White Russian oats is ought to be somewhat rust resistant. The Fifes and Blue Stem (Vel- ot Bald Blue Stem) are almost the only varieties of wheat known by e majority of the farmers. By far the greater proportion of the reals of the State is, of course, grown in the extreme eastern part, or near the fertile James River Valley, and the rusts naturally occur greatest abundance in that region. Nevertheless the orange leaf ist and occasionally the stem rust also are found far westward. Much ist is reported, especially from Nelson, Grand Forks, Cass, Richland, teele, McHenry, and Kidder counties.

South Dakota.—In this State, as in North Dakota, it is, as a rule, too y, cool, and breezy for rusts to do much damage, but nevertheless

they are occasionally quite injurious in places. The leaf rust is the species most common. The Blue Stem and various Fifes are the varieties of wheat generally grown. Oats, especially when planted late, is often badly rusted. Naturally rust is most abundant in the southeastern counties. Rust seems to be quite severe, at least occasionally, in *Kingsbury, Clay, Deuel, Faulk, Brookings, Hanson, Minnehaha, Union,* Douglas and Davison counties.

Nebraska.—Usually wheat is not badly damaged by rust in this State, although sometimes the injury is quite serious. The cereals in large portions of the State were badly injured in 1891, the black stem rust being abundant that year. In the sandy districts there is usually but little trouble with rust. As in Iowa, spring sowing is common, and is doubtless responsible for much of the injury. Fortunately, however, fall sowing is coming into vogue. As is usually the case, rust often accompanies winterkilling and poor drainage. In the eastern portion of the State oats is often severely damaged. The counties from which much rust is reported are Douglas, York, Loup, Dodge, Nuckolls, Blaine, Gage, Custer, Frontier, Nance, Perkins, Hamilton, Greeley, Howard, Adams, Wayne, Cuming, Boone, Seward, and Saline.

Kansas.—In the eastern half of the State the wheat crop is quite often injured by rust, but in the western half the damage is usually insignificant. Notwithstanding its comparative immunity, the writer once saw a field of White Michigan wheat in Cloud County totally destroyed by rust, the probable yield of the field having been estimated a few days prior to the attack at 25 bushels per acre. Turkey wheat is quite resistant to rust and is a general favorite in the State, particularly in the western part, and yet even in that section the writer has seen it severely attacked by the stem rust. Oats is often greatly damaged by stem rust in the eastern portion and is sometimes a total loss. The crop suffered greatly in 1893. Occasionally fields of late-sown oats are entirely destroyed before harvest. The counties in which rust seems to occur most frequently are Rice, Montgomery, Johnson, Stevens, Washington, Linn, Riley, Osage, Jewell, Reno, Marshall, Barton, Coffey, Bourbon, Ottawa, Shawnee, Decatur, and Miami.

Texas.—Reports received from the State during the dry season of 1894 indicate that grain is not usually attacked by rust. However, but little dependence can be placed upon so few reports from so large a State and only for one season, and moreover most of them were from northern Texas and the Panhandle, where there is always considerable drought. On the other hand, the writer knows from personal observation that in the east and south central portions of the State rust has been so detrimental to wheat that this crop has been practically abandoned over an extensive area of excellent wheat land. It is claimed that at the Texas Agricultural Experiment Station rye is actually injured by leaf rust even in midwinter. In fact, rye is often attacked

by this rust in all the Southern States. Oats is seldom injured to any extent. Nicaragua wheat, a durum variety, was totally destroyed in 1896 at the Agricultural College farm in Brazos County. The part of the State in which rust seems to be most severe is that lying east of Gainesville, Fort Worth, and Austin.

Washington and Oregon.—Little information relative to cereal rusts has been obtained from these States, but as far as known they cause only slight damage, except in districts within reach of dampness from the ocean. On account of the growing season being also the dry season, the atmosphere is not usually favorable to rust propagation. Occasionally oats is considerably affected by the crown rust, as was the case in 1892 in Sherman County, Oregon.

California.—Though reports indicate that rust does not commonly injure the grain, still in some places both wheat and oats are severely damaged. The losses seem to be confined almost wholly to the coast districts within the influence of sea fogs. In other parts of the State the atmosphere is usually too dry for the rust to spread. In a few districts along the coast, in parts of Ventura County, for instance, wheat raising is said to have been abandoned on account of rust, but in some districts, as in Mono, Fresno, and San Bernardino counties, rust is extremely rare. Toward the north early wheat is reported by some to be more liable to rust than late, perhaps on account of weakness from winterkilling or frosts. Semihard or soft white wheats are generally raised. Sonora is a common variety and is said to be rather rust resistant. Black oats, it is claimed, is more resistant than white. Some of the counties in which rust seems to be especially plentiful are Santa Clara, Ventura, Sonoma, San Mateo, San Diego, and Santa Barbara.

Montana, Idaho, and Utah.—On account of the cool, dry atmosphere in these States, the rusts seldom occur in sufficient abundance to do any appreciable injury.

Virginia.—According to reports, wheat in the Shenandoah Valley is sometimes badly damaged by rust, and oats is damaged quite often. The rust is most abundant in the lowlands. Lancaster wheat is considered as rather rust resistant.

Oklahoma.—Within the past three years Oklahoma has become an important wheat-producing territory, and in the season of 1897 much injury resulted from rust. There was much rain near harvest time and rust doubtless materially lessened the yield, although it was still very large. In this region May wheat and soft varieties seem to be most subject to rust and Fulcaster and Turkey most resistant.

LOSSES CAUSED BY RUST.

Although several writers have discussed the question of financial losses from the grain rusts in different countries, including the United States, there are as yet no reliable estimates. Could even an approximate estimate of the losses in this country be made it would be very gratifying, but as yet even this can not be done. It would of course

be impossible to make any general estimate from the per cents of damage given in Table 1, as they show the losses for only one or two seasons and in comparatively few localities. In the writer's opinion, however, the average annual loss from rust throughout the United States far exceeds that due to any other enemy, insect or fungous, and often equals those from all others combined.

ORANGE LEAF RUST OF WHEAT.

(*Puccinia rubigo-vera tritici*).

Physiological relations.—It was not until a late date in the writer's inoculation experiments that attention was given to this rust, most of the previous work having been with *P. graminis* and *P. coronata* of oats. Many observations made in the field have shown that the leaf rust of wheat and of rye probably do not pass from one host to the other, but are distinct specialized forms. Where wheat and rye are grown in adjoining fields, rust not only attacks them at different dates (which may be partially accounted for in that rye is in a condition most susceptible to rust earlier than wheat, maturing, as it does, earlier), but is occasionally very prevalent on one and not abundant or even present on the other during the entire season. Again, the writer has never been able to find any relation between the abundance of this rust on wheat and its occurrence on native grasses in the vicinity of the wheat fields.

The writer's first experiments, reported by Hitchcock and himself (39, pp. 3, 4), showed that uredospores of this rust would not infect oats, rye, or orchard grass, and that a uredo (supposed to belong to *P. rubigo-vera*) of Kentucky blue grass would not infect wheat or oats. The results of all subsequent inoculations[1] with this rust are summarized in the table following.

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[1] Unless otherwise explained, all inoculation experiments reported in this bulletin consisted in treating one small pot containing from two to twelve seedling plants of the same kind 10 to 30 days old from the seed in case of cereals and 20 to 40 days in case of other grasses. An average of nine inoculations were made in each experiment, there being never less than six, and rarely more than twelve. The manner of performing the experiment is as follows: The plants to be inoculated are first wet with a very fine spray of water from an atomizer. Then by the use of a thin, narrow-bladed scalpel material is scraped from the diseased plants and is applied in spots here and there on the healthy ones, that is, on the upper surface, the lower surface, or on both, or on the stem also, depending on the particular experiment. No incisions are ever made. After another spraying the plants are covered with a bell jar, and the latter wet with cold water to aid in preserving a coating of moisture on the plants. On an average, the bell jar is not removed for two days, except just for an instant to allow a further spraying with water. During periods of hot sunshine a shade is used to shut off the sun's rays. These experiments are made in the greenhouse even during the summer, and the different rusts are kept growing the year through. All experiments of the same date are, as a rule, accompanied by one check experiment, in which inoculations are made upon plants of the same host as those from which the inoculating material was taken. All inoculations are made with uredospores unless otherwise stated.

TABLE 2.—*Inoculation experiments with Uredo rubigo-vera of wheat.*

Date of inoculation.	Place where experiments were made.	Origin of inoculating material.	Plant inoculated.	Period of incubation (days).	Result.
Jan. 19, 1897	Washington, D. C.	Wheat	Wheat	8	Successful.
Do	do	do	Missogen wheat	8	Negative.
Do	do	do	Rye	8	Do.
Feb. 1, 1897	do	do	Wheat	8	Successful.
Do	do	do	Rye	8	Negative.
Do	do	do	Barley	8	Do.
Do	do	do	Oats	8	Do.
Feb. 12, 1897	do	do	Wheat	11	Successful.
Do	do	do	Taganrog wheat	11	Do.
Do	do	do	Missogen wheat	11	Do.
Feb. 13, 1897	do	do	Wheat	15	Do.
Do	do	do	*Dactylis glomerata*	15	Negative.
Feb. 24, 1897	do	do	Akayemidashi wheat	11	Only one or two spots.
Do	do	do	California white wheat	11	Do.
Feb. 11, 1898[1]	Lincoln, Nebr.	do	*Elymus canadensis*	13	Negative.
Do	do	do	*Elymus canadensis glaucifolius.*	7	Doubtful.
Do	do	do	*Elymus virginicus*	13	Do.
Do	do	do	*Agropyron richardsoni*	13	Negative.
Do	do	do	*Agropyron spicatum*	13	Do.
Do	do	do	*Agropyron tenerum*	13	Do.
Do	do	do	*Dactylis glomerata*	13	Do.
Do	do	do	*Panicum autumnale*	13	Do.

[1] Through inadvertence no check experiment was made.

Two of the experiments were doubtful on account of the slight infections, which were possibly accidental. Although under date of February 11, 1898, no check experiment of inoculations from wheat to wheat was made, in numerous other experiments with wheat alone the inoculations never failed to infect readily, where ordinary cultivated varieties of *Triticum vulgare* were used.[1]

Although the experiments carried on with *Uredo rubigo-vera* were not so numerous as those made with other rusts, they are nevertheless sufficient to show that the limits of this rust form are quite closely circumscribed by physiological conditions. Many more experiments with this rust would have been made during the winter of 1896–97 had it not been for the presence of wheat mildew, which tended to vitiate all work and which could not be got rid of without interfering with the experiments.

The time of incubation, or the interval between inoculation and appearance of rust in the case of *Uredo rubigo-vera* of both wheat and rye, is somewhat longer, as a rule, than that of the other cereal rusts, ranging under usual conditions in the greenhouse from seven to ten days.

The experiments so far made indicate that only varieties of the following species and subspecies[2] of the genus Triticum act as hosts for

[1] A fact of interest in this connection is that in one experiment Missogen, a hard wheat, of the subspecies *Triticum durum*, from Greece, showed no infection. Although this may not seem very significant at first, yet if considered in connection with facts shown in Table 8, it will be found to be in accord with the results of experiments on rust resistance of varieties given in Table 3, which show that durum and poulard wheats are more resistant to orange leaf rust than are the bread wheats.

[2] The classification of wheats followed in this bulletin is that of Koernicke and Werner (41).

the orange leaf rust of wheat in this country: *Triticum vulgare, T. compactum, T. turgidum, T. durum, T. spelta, T. dicoccum*, and *T. polonicum*. These are all cultivated varieties, but varieties of the three last named have been grown so far in this country only in an experimental way.

Occurrence and distribution.—It is a well-established fact that the orange leaf rust of wheat is the most common and widely distributed of all the cereal rusts in the United States, and is especially the most constant in occurrence from year to year. The stem rust and the crown rust do not occur on cereals in certain years and certain localities. The orange leaf rust of rye, although occurring wherever rye is grown, is still not common, because rye is not grown generally. Maize rust usually occurs wherever corn is grown, but is seldom abundant; but the orange leaf rust of wheat is not only never absent from the wheat field, being there the year through, but is sometimes abundant even in dry seasons. There is still so much uncertainty as to the identification of species that as yet it can not be definitely said whether this rust is the most common in foreign countries also, but the probabilities are that it is, at least in all except the countries of northern Europe. In Australia and India there is no doubt of its being the most common, provided that our leaf rust and the one in these countries are equivalent, which is almost certain. Barclay (5, Vol. XXVIII, p. 257; Vol. XXX, p. 46) is quite emphatic as to its being the most common in India.[1] In Sweden the conditions seem to be exceptional. The most common, as well as the most injurious rust in that country, according to Eriksson (31, pp. 208, 209, 331), is *P. glumarum*, while *P. dispersa* is rather insignificant both as to its occurrence and the injury it causes.[2]

Wintering of the uredo.—So much has already been written concerning the wintering of the uredo and the ability of the fungus to readily pass the winter in the uredo stage is so well established for this country that there is little further to add. However, it may perhaps be well to state that the conclusions of Bolley (7, pp. 13–15) and of Hitchcock and the writer (39, pp. 1, 2) have been confirmed and reconfirmed by the writer both in Kansas and Maryland. In the Southern States the leaf rusts of both wheat and rye not only live, but grow all winter. It is now conclusively proved that in latitudes below 40° in this country the leaf rust of wheat is able to pass a perpetual existence in the uredo stage on wheat alone, without the intervention of any other stage. This is evidently a matter of much economic importance, for if this method is not only possible, but should turn out to be the only one, it is easy to

[1] *Through the kindness of the Government officials of India the writer received* specimens of rusted wheat straw from that country. The rust most abundant on the specimens seems to be morphologically enough like our own *Puccinia rubigo-vera* to be called the same, specimens showing the second and third stages of this rust being present. However, *P. graminis* was also found in considerable amount.

[2] At the writer's request Dr. Eriksson kindly sent him specimens of both *P. glumarum* and *P. dispersa*. An examination of these specimens showed that with the exception of a slight difference in color there is a very close resemblance morpho-

see how the fungus might be easily overcome.[1] At all events the writ is convinced that the existence of volunteer wheat must have conside able bearing upon the distribution and propagation of this rust, an the conviction will be strengthened should further experiments fail t reveal other hosts besides wheat. There is still a possibility, howeve that some native grass harbors the same rust form. In Australia it generally accepted as a fact that both *Puccinia rubigo-vera* and *l graminis* exist in the "red rust" stage all the year through, either o self-sown grain or on native grasses. Cobb (19, p. 29) and Lowrie (4 p. 51) make particular references to the matter. However, it shoul be remembered that identification on morphological grounds alone not sufficient to prove that the grasses mentioned actually bore the cereal rusts and no mention is made of inoculation experiments.

The observations made thus far in India do not indicate that th rust lives the entire year in the uredo stage on any host. Barcla after careful investigation, failed to discover a continuous repetition urcdospores (5, Vol. XXX, pp. 47, 48), though he admits the possibilit of such. He thinks such an occurrence more improbable than "i Europe, where crops both of cereals and wild grasses overlap o another." Prain (60, p. 27) and Watt (70, pp. 54–56) discuss this que tion and accept Barclay's conclusions.

Eriksson has failed to discover that any one of the wheat rusts liv throughout the year in the uredo stage in Sweden. He claims to hav shown, however, that *P. glumarum* is perennial within the wheat plan (25). To account for this he proposes a new theory, which will b

[1] Dr. Geo. Watt, editor of the Agricultural Ledger of India, makes quite unfavo able criticisms (70, pp. 55, 56) of the conclusions reached by Hitchcock and the writ concerning this matter, as given on page 9 of our second report on rusts of grai After quoting these conclusions he says: "The criticism would seem fairly justi able, however, that these opinions are based on purely artificial experiments. Th experiments may, in fact, be said to show what might occur, not by any means wh occurs. It would, of course, be possible (under glass in cold countries or by redu ing the temperature in tropical regions) to supply the parasite with continuou crops of its host, and thus to produce uredospores for an indefinite period. * * The Kansas reports do not seem to afford sufficient evidence in support of the view advanced. * * * In countries that do not have a severe climatic isolation betwe the seasons of wheat cultivation, volunteer survivals of the crop might easil enough occur. Where this is met with the existence of uredospores might be mad a matter of actual observation, and their vitality tested at repeated intervals, with out having to call in the aid of improbable experiments." But a more careful read ing of the bulletin will show that the "opinions" mentioned are not "based o purely artificial experiments," though greenhouse experiments were indeed employe to confirm field observations. It is distinctly stated on page 2 of the report name that the rust was observed in the field at different times, up to March 22, and o course after that date rust would continue to grow in that latitude. In the mean time, to prove that in these rust spots the spores were actually alive, many of the were brought in at various times and germinated and healthy plants infected wit them, thus "testing their vitality" exactly as Dr. Watt suggests should be done More than this, diseased plants were occasionally transplanted into the greenhouse and as fresh uredospores were produced before a period of incubation from inocula

referred to further on. Sorauer (65, p. 216) states that the uredo mycelium of *Puccinia straminis* (*P. rubigo-vera*) winters over without injury. The inference is that the locality he has in mind is some portion of Germany, but whether he means *P. glumarum* or *P. dispersa* of Eriksson and Hennings, and whether the host plant is wheat or rye, is not known.

Liability of different varieties to this rust.—The study of the comparative liability of different wheat varieties to rust has in recent years developed to such an extent that an elaborate paper might be written on this topic alone. To investigate this phase of the subject the writer conducted a rather exhaustive series of field experiments during the seasons of 1895, 1896, and 1897, and as the orange leaf rust was the one mainly dealt with the question of rust resistance will be discussed at length here.

At the outset much time was required to learn what varieties are grown in different parts of the world and the sources through which they might be obtained. Efforts to obtain the varieties of each country were begun early in the spring of 1894, but many of those from distant parts did not arrive even in time for planting in the autumn of 1895. Peter Henderson & Co., of New York City, agreed to aid in obtaining foreign varieties through their foreign agents. In addition to those obtained in this way, samples were sent in direct by William Farrer, of New South Wales; Prof. E. M. Shelton, of Queensland; Prof. S. Tanaka, of the Imperial University, Tokyo, Japan; Carter Bros., of London, England; and Mr. H. Vagnon, Kherba, Clos des Bras, Algeria. In this country and Canada varieties were obtained from the agricultural experiment stations of Michigan, North Dakota, Nebraska, Kansas, and New Mexico; from Prof. William Saunders, of the Central Experimental Farm, Ottawa, Canada; and from Mr. A. N. Jones, of Newark, N. Y. Varieties were obtained from every important wheat country in the world. The record of experiments shows over 1,200 varieties, but of course many of these were duplicates, and about 75 were Farrer's unfixed crossbreds. Notwithstanding this, however, there were certainly over 900 good varieties tested during the three years of experiment. A very large number of these varieties, 463 in all, came from New Mexico through Prof. A. E. Blount, who has done so much work in breeding wheats, and who has collected a great many varieties from different countries. These were especially valuable in that they included a number of Blount's crossbreds and also many foreign varieties more or less acclimated to this country.

The experiments of 1895 were conducted at Garrett Park, Md., those of 1896 at Salina, Kans., and those of 1897 at Manhattan, Kans. The soil at Garrett Park was first treated with a fertilizer commonly used for wheat in that region and composed of South Carolina rock, bone dust, and kainit, the application being made at the rate of 500 pounds per acre while the ground was being harrowed. The different varieties

long and 12 inches apart at Garrett Park, 20 feet long and 12 inch apart at Salina, and 25 feet long and 20 inches apart at Manhatta The time of seeding extended from October 17 to November 28, man of the foreign varieties being sown exceedingly late on account their late arrival in this country. In the experiments at Garrett Par all the varieties, except those from New Mexico and Farrer's crosse were seeded in two to four rows each.

The orange leaf rust was the only species that occurred at Garret Park, but it was extremely abundant, and therefore there was an exce lent opportunity of testing the resistance of the different varieties this rust. After this year it was thought best to continue the exper ments in the States of the Plains, as they more truly represent th conditions of the greater part of our wheat region, and, moreover, th stem rust as well as the leaf rust is nearly always present in the region. Hence the work was transferred to Kansas. Both rust attacked the wheat at Salina and at Manhattan, the leaf rust being th more common. At Salina, as at Garrett Park, all varieties were plante rather late because of the drought, the dates of seeding extendin from October 16 to November 4. At Manhattan all but about a doze of the varieties were seeded in good time, that is, on September 22 an 23. The seeding of spring varieties was done each year at the averag time for such seeding.

The winters of 1895–96 and 1896–97 were both unusually severe i the localities where the experiments were conducted, hence hundred of the imported varieties failed entirely during these two seasons, an only a small proportion of the whole number tested during the thre years withstood the climatic rigors and produced seed at the close o the season at Manhattan. It is interesting to note, however, that number of sorts, especially those of Russian origin, passed the winte at Manhattan in much better condition than most of the varieties reg ularly grown there by the experiment station (36a, pp. 172–174).

The rust liability of the different varieties was determined by notin the per cent of rust on each at the date when the rust was mos abundant.[1]

The experiments at Salina were conducted on the farm of Mr. B. B Stimmel, who kindly gave the necessary ground free of charge. Throug the *courtesy of the board of regents of the State Agricultural Colleg* at Manhattan, the farm department cooperated with this Departmen in carrying on the experiments on its land and furnished certain aid i the prosecution of the work. For the successful accomplishment of th

[1] If no rust spot could be found on any plant in the row, the per cent of rust wa of course zero; if only one or two spots were present on each of the plants in a hal dozen or more places, the amount of rust was estimated as 1, 2, or 3 per cent, and s on; if nearly all the leaves in the row were about half covered with rust, it wa estimated as 50 per cent; and if they were practically covered, it was estimated a 100 per cent. Of course the estimates were necessarily approximate and, moreover the scale of rusts varies according to individual ideas. In this case the rust was e

work at Garrett Park great credit is due Mr. P. H. Dorsett, of this Division, who rendered valuable assistance.

The principal results of the three years' experiments are arranged in as condensed a manner as possible in the following table. In every case where the rust could not be graded for more than one season the variety is omitted from the table. Nearly every instance of this kind was in the case of a variety that winterkilled or failed otherwise after the first season, but in some cases they were simply not at hand for planting more than the one season. As a result of this disposition only about one-third of the varieties actually planted during the three years are represented in the table; hence it shows no varieties from Greece, England, Holland, India, Siberia, Argentina, or Algeria, although they were obtained from each of these countries. In the case of the varieties from Argentina and Algeria they were simply received too late to be tested except in the severe season of 1896–97.

Only those who have had similar experience can form any idea as to the work required to keep the nomenclature of varieties from being confused. It is not claimed that all the names in the table are right, for such a claim would be preposterous; but it is believed that nearly all are fairly reliable, or at least as correct as they can be in the present confused condition of our wheat nomenclature. Moreover, many apparent errors are really the correct names, the seeming discrepancy arising from translations of the original name into a different language, or they are cases of pure synonyms; for instance, Kaiser and German Emperor are very probably the same variety, while Kubanka and Beloturka, Black Sea and Arnautka, Thick-set and Cone Rivet, Club wheat and Oregon Club, Genealogic and Hallets Pedigree, Soules, Flint and Yorkshire, German Amber and Amber Winter, De Bordeaux and Rouge Inversible, etc., are all cases of synonyms. The peculiarity of some of the names is doubtless due also to bad orthography, as for example, a certain hybrid is not Tamed but Lamed. In French names incorrect spelling is common and in Russian names it is the rule. Sometimes such simple names as Gold Drop and Blue Stem are applied incorrectly to the most widely different varieties, and such names as Turkey and Russian Red either mean very little or may even be misleading, giving no clue to the origin of the varieties as one might suppose. A thorough revision of the nomenclature of our varieties of wheat is a most important desideratum for this country.

The two main obstacles to a successful comparison of the rustiness of a large number of varieties according to the method followed in the experiments, are (1) that the varieties being necessarily planted at different dates those equally susceptible to rust may nevertheless not be equally rusted at the time of grading, and (2) it is impossible to carefully grade the rustiness of [...] red varieties a day. However, in case of [...] both obstacles were overcome to a consi[...] arieties each season in the order in whic[...] standing this, many

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of them afterwards became more rusted than they were at the date of grading, though this did not occur to any great extent except in 1895. In that year, for example, though a few of the varieties showed no rust at all at the date of grading, yet only one variety, Einkorn, remained absolutely rust proof throughout the season. Much value would have been added to the experiments if they could have been continued in each locality during the three seasons, but under the circumstances this was impracticable. It is hoped, however, that they have settled a few things definitely and that they will furnish a valuable groundwork for future experiments in this country.

TABLE 3.—*Comparative amount of Uredo rubigo-vera on different varieties of wheat.*

Localities and names of varieties of—	Bald or bearded.	Per cent of rustiness of varieties in— 1895. May 23–25.	1895. June 13–17.	1896. June 15–16.	1897. June 22–25.	Average.	Remarks.
WINTER WHEATS.							
New Mexico:							
Algerian No. 1	Bearded	......	2	40	......	21	Durum wheat.
Algerian No. 3	do	......	3	20	......	12	Do.
American	do	x[1] m[2]	95	50	55	67	
Ames	do	m	0	60	......	60	Do.
Amethyst	Bald	x	10	50	......	30	Blount's cross.
Andrews	Bearded	m	92	20	......	56	
Andrus Black	do	......	5	15	......	10	
Aowse	Bald	m	70	50	......	60	
Armstrong	do	x m	68	30	......	50	
Arnolds Hybrid	do	x m	75	25	60	53	
Australian Indian	......	......	30	20	......	25	
Baltimore	Bald	m	90	25	......	58	
Banater	Bearded	m	5	20	......	13	
Bennett	do	......	60	50	......	55	
Berthoud	Bald	......	60	30	......	45	
Big English	do	m	93	10	55	53	
Black Chaff	Bearded	x m	40	35	......	38	
Blue Stem	Bald	x m	65	40	......	53	
Boyer	Bearded	x	70	50	20	47	
Buckeye	Bald	m	80	[3]*33	50	54	* Mean of two grades.
California Walker	do	......	75	55	60	63	
Canadian Wonder	Bearded	m	92	20	......	56	
Carters H	Bald	x m	5	50	......	28	
Carters I	Bearded	x m	20	60	......	40	
Carters J	Bald	x m	4	45	......	25	
Champion Amber	do	x	80	35	......	58	
China Red	Bearded	......	50	25	......	38	Hard wheat.
China Tea	do	......	20	55	......	38	Do.
China White	do	......	40	60	50	50	Do.
Clawson	Bald	......	15	40	57	37	
Crotan	Bearded	m	0	40	......	20	A durum wheat.
Daud Khan No. 2	Bald	......	5	30	......	18	White hard wheat.
Davis	do	......	65	40	......	53	
Deitz Amber	Bearded	......	82	60	......	71	
Dera	......	......	20	50	......	35	
Early Jasper	Bearded	......	60	45	......	53	
Early May	Bald	m	60	25	......	43	
Early Rice	......	......	97	30	......	64	
Early Ripe	......	m	88	50	55	64	
Earnhardt	Bald	m	65	50	50	55	
Egyptian F	do	......	40	55	......	48	
Egyptian No. 1	do	......	93	30	......	62	
Emporium	do	x	88	35	......	62	
Essex	do	m	40	*20	......	30	* Mean of two grades.
Fairchild	Bearded	m	98	20	......	59	
Farquhar	Bald	m	98	50	......	74	
Fleck	do	m	45	30	......	38	

[1] x indicates that such varieties were just beginning to rust at the date of grading.
[2] m indicates that the variety was badly attacked and sometimes severely injured by mildew (*Erysiphe graminis*) at the time of grading.
[3] Marks of reference (*, †) in this table call attention to explanations in last column.

TABLE 3.—*Comparative amount of Uredo rubigo-vera on different varieties of wheat*—Continued.

Localities and names of varieties of—	Bald or bearded.	Per cent of rustiness of varieties in— 1895. May 23–25.	1895. June 13–17.	1896. June 15–16.	1897. June 22–25.	Average.	Remarks.
WINTER WHEATS—continued.							
New Mexico—Continued.							
Flourello	Bald	m	95	60	......	73	
Fluor Spar	do	m	60	50	......	50	Blount's cross.
Frances	do	m	75	50	......	63	
Frankenstein	do	m	60	40	......	50	
Freeling	do	m	30	50	......	40	
French Black Chaff	do	......	70	55	......	63	
Fulcaster	Bearded	......	92	35	......	64	Semihard wheat.
German Amber	Bald	......	80	60	40	60	
German Emperor	do	......	95	50	......	73	
Glass	do	......	45	30	......	38	
Gold Drop	do	m	80	25	70	55	
Golden Chaff	do	......	20	55	......	38	
Gold Premium	do	m	60	50	50	53	
Granite	do	m	30	50	......	40	Blount's cross.
Gypsum	do	m	15	50	......	33	Do.
Gypsy	Bearded	m	98	30	......	64	
Hard Australian	Bald	m	60	50	......	55	
Hard Manitoba	do	m	70	25	......	48	
Heiges Prolific	do	x m	75	45	......	60	
Hicks Prolific No. 1	do	m	75	40	......	58	
Hornblende	do	......	15	55	......	35	Do.
Hungarian	Bearded	m	72	50	......	61	
Hunters Winter	Bald	m	60	30	......	45	
Illinois Second Premium	do	x	75	35	......	55	
Improved Fife	do	m	20	40	......	30	
Improved Rice	do	......	85	40	......	63	
India Red	do	m	80	45	35	53	
Jacinth x Baart	Mixed	m	60	45	......	53	Farrer's cross.
Jennings	Bald	m	98	50	......	74	
Johnson	Bearded	m	92	50	......	71	
Jones Square Head	Bald	m	98	50	......	74	Jones's cross.
Kings Jubilee x Tourmaline	do	......	50	20	......	35	Farrer's cross.
Kivet	do	m	70	50	......	60	
Lairds Prolific	do	m	20	50	......	35	
Landreth	do	x m	95	35	......	65	
Leake	do	......	10	30	......	20	From Australia.
Lehigh	Bearded	m	75	50	......	63	
Lincoln	Bald	m	95	30	......	63	
Little Wonder	do	m	25	40	......	33	
Longberry	do	m	98	65	55	73	
Mammoth	do	m	15	50	......	33	
Martins Amber	do	m	92	*45	......	69	* Mean of two grades.
McCreagan	do	m	96	30	......	63	
McGees Red	Bearded	......	60	35	......	48	
Mediterranean Hybrid	Bald	......	80	10	......	45	
Mediterranean Spring	Bearded	......	20	50	......	35	Hard wheat.
Mennonite	do	m	20	50	45	38	Do.
Michigan Amber	Bald	......	30	30	......	30	
Midge Proof	do	m	65	60	......	63	
Millers Prolific	do	m	98	50	......	74	
Minnesota Fife	do	......	5	40	......	23	Do.
Missouri Mediterranean	Bearded	......	70	25	......	48	Do.
Missouri Turkey	do	m	65	40	55	53	Do.
Monarch	do	m	95	55	......	75	
Moscow	do	m	25	50	......	38	Do.
Nashi	do	......	10	50	60	40	Very hardy.
Niagara	Bald	m	70	50	......	60	
Nigger	Bearded	m	85	15	65	55	Hardy.
North Champion	Bald	m	35	20	......	28	
Northcotes Amber	do	m	40	60	......	50	
Nox No. 3	do	m	40	10	......	25	
Oakshotts Champion	Mixture	m	55	30	......	43	
Odessa	Bald	m	1	40	45	43	Hard wheat.
Odessa No. 1	do	m	99	55	55	70	Hard-grained.
Odessa No. 2	do	m	97	65	65	76	Do.
Odessa No. 3	do	m	97	55	......	76	
Odessa No. 4	Bearded	m	90	50	......	70	
Osterey	Bald	m	95	20	......	58	Do.
Palestine	do	x m	10	20	......	15	A durum wheat.
Patagonia	do	m	94	60	......	77	
Platinum	do	m	40	......	70	55	Blount's cross.

TABLE 3.—*Comparative amount of Uredo rubigo-vera on different varieties of wheat*—Continued.

Localities and names of varieties of—	Bald or bearded.	Per cent of rustiness of varieties in— 1895. May 23–25.	1895. June 13–17.	1896. June 15–16.	1897. June 22–26.	Average.	Remarks.
WINTER WHEATS—continued.							
New Mexico—Continued.							
Pollard	Bald	......	50	60	......	55	
Pooles Red	do	......	40	50	......	45	
Porcelain	do	m	40	60	......	50	Blount's cross.
Powers	do	m	95	30	......	63	
Pringles No. 5	do	m	5	60	35	39	Hardy variety.
Propoe	do	x m	60	30	......	45	
Prussian	do	......	35	50	......	49	
Purple Straw	do	x	55	70	......	63	
Quartz	Bearded	......	15	......	55	35	Blount's cross.
Raubs Prolific	Mixed	......	68	50	......	69	
Red Brazilian	do	m	94	*20	......	57	* Selected bald.
Red May	Bald	x	68	*40	......	64	* Mean of two grades.
Rieti	Bearded	......	5	50	......	28	Hardy sort.
Rieti No. 1	do	m	40	30	......	35	
Roberts	Mixed	m	98	15	......	56	
Rocky Mountain	Bald	m	80	30	......	65	
Rogers	do	m	80	50	......	65	
Roseworthy		......	30	45	......	38	Early variety.
Rudy	Bearded	m	98	35	......	67	
Rural	do	......	0	5	......	3	Flinty-grained.
Russian	Bald	m	5	20	......	13	Hard-grained.
Russian Hard	Bearded	m	60	50	50	53	Hardy and hard grained.
Rye Wheat	Bald	m	50	50	......	50	
Santa Fe	do	m	92	*63	......	78	* Mean of two grades.
Scott	Bearded	......	80	55	......	68	
Sherman	do	......	5	50	......	28	
Silver Chaff	Bald	x	65	55	......	60	
Small Frame	do	x m	90	50	......	70	
Smoky	Bearded	m	25	45	......	35	
Soules	Bald	......	94	50	......	72	
Tappahannock	do	m	90	45	......	68	
Touzelle	Bearded	......	5	50	......	28	
Treadwell	Bald	x m	93	*50	......	72	Do.
Triticum	Bearded	......	15	35	55	35	Hardy sort.
Tuskana	Bald	m	50	40	......	45	
Valley	Bearded	m	95	50	......	73	
Varesotto	do	m	70	60	......	65	
Veneto	do	m	65	60	......	63	
Verplank	Bald	m	85	65	......	75	
Walker	do	x m	75	40	60	58	
Wards Prolific	do	......	45	50	......	48	From Australia.
Wards White x Tourmaline	do	......	65	50	......	58	Farrer's cross.
Weeks	Bald	m	75	60	......	68	
White Michigan	do	......	5	35	......	20	
White Rose	do	......	91	45	......	08	
White Russian	Bearded	......	5	40	......	23	Hard wheat.
Whites	do	......	25	30	......	28	
White Velvet	Bald	m	40	20	......	30	
Wicker	do	m	70	30	......	50	
Winnipeg	Bearded	......	0	15	......	8	A durum wheat.
Winter Australian	Bald	m	10	60	......	35	
Wintergreen	do	m	75	55	......	65	
Winter Pearl	do	......	97	50	......	74	
Witter	do	m	97	55	......	76	
Yellow Missouri	do	m	50	55	......	53	
Yuba	Bearded	m	98	50	......	74	
Kansas:							
Badger	Bald	x m	85	10	......	48	
Big English	do	x m	75	40	......	50	
Big Frame	do	x m	90	10	......	58	
Buckeye	do	x m	75	30	60	55	Hardy wheat.
Currell	do	m	50	40	......	45	
Dallas	Bearded	m	85	65	45	62	Hardy sort.
Deitz	do	......	85	15	......	50	
Diehl Egyptian	Bald	m	98	45	......	71	
Early May	do	x m	78	40	50	56	Early variety.
Farquhar	do	m	90	20	75	62	Hardy.
Fultz	do	x m	96	50	60	69	Hardy sort.
Improved Rice	do	x m	94	50	......	72	
McCracken	do	m	94	45	......	70	
McPherson	do	m	90	45	......	68	

TABLE 3.—*Comparative amount of Uredo rubigo-vera on different varieties of wheat*—Continued.

Localities and names of varieties of—	Bald or bearded.	Per cent of rustiness of varieties in— 1895. May 23–25.	1895. June 13–17.	1896. June 15–16.	1897. June 22–25.	Average.	Remarks.
WINTER WHEATS—continued.							
…nsas—Continued.							
Nigger	Bearded	x m	96	30	65	64	Hardy.
Oregon Club	Bald	m	5	30	......	18	
Penquites Velvet Chaff	Bearded	m	80	25	......	53	
Ramsey	Bald	m	96	30	......	63	
Seneca Chief	Bearded	m	88	70	......	79	
Tasmanian Red	do	m	55	50	......	53	Hard wheat.
Velvet Chaff	do	x m	93	20	60	58	Fairly hardy.
White Blue Stem	do	x m	94	45	......	70	
Yellow Alabama	....	m	95	50	......	73	
Zimmerman	Bald	m	93	50	70	72	Hardy sort.
North Dakota:							
Glyndon No. 669	do	m	75	40	......	56	
Glyndon No. 692	do	m	74	30	......	52	
Glyndon No. 768	do	m	70	45	......	58	
Glyndon No. 775	do	m	70	50	......	60	
Powers Fife	do	m	70	35	......	53	
Red Fife	do	m	50	50	......	50	
Nebraska:							
Brazilian Red	Bearded	m	92	* 28	......	60	* Mean of two grades.
Coryell	Bald	m	89	50	......	70	
Deitz Longberry	Bearded	m	87	50	......	69	
Golden Prolific	Bald	x m	95	65	......	80	
Ironclad	do	m	50	50	......	50	
Mediterranean	Bearded	x m	88	25	......	57	Hard wheat.
Miller	Bald	m	91	40	......	66	
Missouri Blue Stem	Bearded	m	92	50	......	71	
New Australian	Bald	x m	92	30	......	61	
Nigger	Bearded	x m	88	30	......	59	
Reliable	do	m	89	50	......	70	
Sea Island	....	m	70	50	......	60	Do.
Tasmanian Red	Bearded	m	91	20	......	55	Do.
Wellington Fife	Bald	x m	93	70	......	82	
			June 21–23				
Michigan:							
Budapest	....	......	......	* 75	50	63	Do. * Spring sown.
Dawsons Golden Chaff	....	......	......	* 75	(†)	75	*Do.* † Winterkilled.
Australia:							
Allora Spring	Bearded	......	* 35	55	......	45	Early variety. * Mean of two grades.
Australian Talavera	Bald	......	* 55	50	......	53	Do.
Battlefield	do	......	35	55	......	45	
Berthoud	*do*	......	*10*	*50*	......	*30*	
Blounts Lambrigg	do	......	* 3	45	......	24	Do.
Brown-eared Mummy	Bearded	......	10	20	......	15	A poulard wheat.
Cape	Bald	......	65	50	......	58	
Clawson	do	......	92	50	......	71	
Dallas	Ba	......	10	20	......	15	
D'Arblays Hungarian x Improved *Fife*.	Mixed	......	* 65	† 50	45	53	* Rustiness not uniform. † Selected bearded.
D'Automne Rouge Barbu x 42 (A).	do	......	* 70	......	† 50	60	* Rustiness not uniform. † Selected bald.
Fill Bag	Bald	......	5	40	......	23	
Fluor Spar	do	......	* 28	60	......	44	* Mean of two grades.
Fort Collins	*do*	......	*60*	*80*	......	*70*	
Frames Early	do	......	75	70	......	73	
French Early Bearded	Bearded	......	20	70	......	45	
High Grade	Bald	......	85	20	......	53	
Hudsons Early Purple Straw	do	......	55	40	......	48	
Improved Fife x Early Japanese.	Mixed	....	70	* 30 † 20	....	50 45	* Selected bald. † Selected bearded.
Jordans	Bald	......	* 43	40	......	42	* *Mean of two grades.*
Northern Champion	do	......	25	75	......	50	
Pringles Defiance	do	......	30	50	......	40	
Pringles No. 5	do	......	* 45	20	......	33	Do.
Rattling Jack	do	......	40	20	......	30	
Ratling Tom	do	......	60	70	......	65	
Red Provence	do	......	70	65	......	68	

TABLE 3.—*Comparative amount of Uredo rubigo-vera on different varieties of wheat*—Continued.

Localities and names of varieties of—	Bald or bearded.	Per cent of rustiness of varieties in— 1895. May 23-25.	1895. June 21-23.	1896. June 16-18.	1897. June 22-25.	Average.	Remarks.
WINTER WHEATS—continued.							
Australia—Continued.							
Red Tuscan	Bald	......	80	20	......	50	
Rieti	Bearded	......	15	20	......	18	
Robins Rust-resistant	Bald	......	*58	80	......	68	* Mean of two grades
Saskatchewan Fife	do	......	75	50	......	63	Hard wheat.
Summer Club	do	......	*50	30	......	40	* Mean of two grades
Tourmaline	do	......	*83	50	......	67	Do.
Vermont	do	......	*38	50	......	44	Do.
Victorian Defiance	do	......	*78	45	......	62	Do.
Wards Prolific	do	......	*55	50	......	53	* Mean of four grades
White Hogan	do	......	20	50	......	35	
White Naples	do	......	80	75	......	78	
White Tuscan	do	......	30	40	......	35	
58 (A)	Bald	......	*50	50	......	50	* Mean of two grades
58 (A) x Blounts Fife	do	......	40	70	......	55	Farrer's cross.
Japan:			June 28-July 1.				
Onigara	Bearded	......	15	75	......	45	Rather hardy.
Yemide	do	......	20	60	......	40	
Persia:							
Prophet	do	......	30	50	......	40	
Reddish White Bearded	do	......	30	50	......	40	
White Bearded	do	......	30	*30	......	30	* Mean of two grades
Turkey:							
Huffkani	Bearded	......	5	5	......	5	Hard wheat.
Kastamuni	Bald	......	*20	55	......	38	* Mean of two grades
Germany:							
Bart März	do	......	60	30	......	45	
Best Summer Club	Bald	......	60	40	......	50	Much mildewed in 189
Blanc a Duvet Veloute	do	......	40	75	......	57	Velvet ears.
Boca Nera	Bearded	......	*0	5	......	3	* Mean of two grades
California Spring	Bald	......	60	40	30	43	
Dattel	do	......	*38	*45	......	39	Do.
Dividenden	do	......	*35	50	......	43	Much mildewed i 1895. * Mean of tw grades.
Egyptian Bearded	Bearded	......	40	40	......	40	Mildewed in 1895.
Fern	Bald	......	5	50	......	28	
Gallician Spring	do	......	50	50	......	50	
Geant du Milanais	Bearded	......	*2	10	......	6	* Mean of two grades.
Goldene Aue	Bald	......	50	30	......	40	
Hickling	do	......	*13	50	......	32	Much mildewed i 1895. * Mean of tw grades.
Igel mit Grannen	Bearded	......	*10	40	......	25	Do.
Kaiser	Bald	......	30	40	......	35	Badly mildewed i 1895.
Mai	Bald	......	*3	20	......	12	* Mean of two grades.
Mirado	Bearded	......	0	5	......	3	Poulard wheat.
Probsteier	Bald	......	2	55	......	29	Badly mildewed i 1895.
Regenerirter	do	......	40	60	......	50	Do.
Romanello	do	......	30	45	......	38	
Rouge de St. Laud	do	......	25	50	......	38	Much mildewed in 1895
Russian	Bearded	......	40	40	......	40	Mildewed in 1895.
Rye Wheat	Bald	......	40	*52	......	46	* Mean of two grades.
Sandomir	do	......	10	50	......	30	Much mildewed in 1895
Smogger	do	......	50	45	......	48	Do.
Taganrog	Bearded	......	1	5	......	3	Macaroni variety Badly mildewed i 1895.
Talavera de Bellevue	do	......	10	50	55	38	Hardy variety.
Urtoba	Bald	......	*16	55	......	36	* Mean of two grades.
Victoria de Mars	Bearded	......	*40	20	......	30	Do.
Spelts, emmers, etc.:							
Bearded White Spring	Bearded	......	60	60	......	60	
Black Velvet Compound Emmer.	do	......	5	15	......	10	
Black Velvet Emmer	do	......	40	25	......	33	
Blue Velvet Bearded	do	......	30	50	......	40	Badly mildewed in 1895.

ABLE 3.—*Comparative amount of Uredo rubigo-vera on different varieties of wheat*—Continued.

Localities and names of varieties of—	Bald or bearded.	Per cent of rustiness of varieties in— 1895. May 23–25.	1895. June 28–July 1.	1896. June 15–16.	1897. June 22–25.	Average.	Remarks.
WINTER WHEAT—continued.							
ermany—Continued.							
Spelts, emmers, etc.—Continued.							
Einkorn	Bearded	......	0	0	......	0	Absolutely rust proof.
Red Tyrol	Bald	......	30	30	......	30	
Red Winter Club	do	......	50	15	......	33	
Schlegel Dinkel	do	......	40	30	......	35	Much mildewed in 1895.
Triticum spelta æstivum	do	......	50	*50	......	50	*Mean of two grades.
Triticum spelta dasyanthum	Bearded	......	50	51	......	51	Badly mildewed in 1895.
Vögeles Dinkel	Bald	......	70	50	......	60	Do.
White Winter Bearded	Bearded	......	50	50	......	50	
aly:							
Bianchetto	Bald	......	70	*30	55	53	Hardy variety. *Mean of two grades.
Bordeaux	Mixed	......	50	45	......	48	
Cologna	Bearded	......	60	50	......	55	
Di Noé d'Umbria	Bald	......	70	45	......	58	
Duro di Apulia	Bearded	......	0	50	......	25	
Duro Riscole	do	......	50	45	......	48	
Lutaba	Mixed	......	70	60	......	65	
Majorica Cianco	Bald	......	80	20	......	50	
Marzuolo	Bearded	......	60	40	......	50	
Precocissimo di Giappone	do	......	75	50	......	63	
Prolifero	do	......	60	40	20	40	Good, hardy variety.
Rieti	do	......	40	40	......	40	
Rieti (prima reproduzione)	do	......	60	40	......	50	
Tangarotto	do	......	0	40	70	37	Hardy sort.
Triminia	do	......	10	20	......	15	
Varesotto	do	......	80	50	......	65	
Vulgo Granillo e Salerno Misto.	Mixed	......	40	20	......	30	
rance:							
A Six Rangs	Bearded	......	2	50	......	26	
Blanc de Flandres	Bald	......	65	30	......	48	
Chiddam d'Automne à Epi Rouge.	do	......	50	50	......	50	
Chiddam de Mars	do	......	30	50	......	40	
D'Australie	Bearded	......	0	40	......	20	Poulard wheat.
De Noé	Bald	......	40	10	......	25	
Hybride de Bordier	do	......	40	40	......	40	
Hybride Hatif (Rimpau)	do	......	50	15	......	33	
Petanielle Noire de Nice	Bearded	......	0	20	......	10	Do.
Richelle Blanche de Naples	Bald	......	65	50	......	58	
Touzelle Rouge de Provence	do	......	70	50	......	60	
Victoria d'Automne	do	......	30	50	......	40	
pain:							
Candeal Desraspado de Murcia.	Bearded	......	60	40	......	50	
Cartagena Rojo Aristado	do	......	50	40	......	45	Semihard wheat.
Jejar de Valencia	do	......	65	30	......	48	Very hard-grained.
weden:							
Kubb	Bald	......	70	40	......	55	
ussia:							
Banatka	Bearded	......	......	50	20	35	Hard wheat.
Bearded Winter	do	......	......	50	50	50	Hardy sort and hard wheat.
Champion	......	......	......	55	60	58	
Crimean	do	......	......	55	40	48	Hardy sort and hard-grained.
Donka	......	......	......	40	50	45	Hard wheat.
Genealogic Red	......	......	......	*50	45	48	Hard wheat. *Mean of two grades.
Kalinovka White	Bearded	......	......	*45	60	53	*Mean of two grades.
Pulavka	do	......	......	50	50	50	Hard wheat.
Red Bearded	do	......	......	*53	60	57	Hard wheat. *Mean of two grades.
Red Winter	Bald	......	......	*55	60	58	Hard-grained. *Mean of two grades.
Russian-English	do	......	......	*65	50	58	Hard wheat. *Mean of two grades.

TABLE 3.—*Comparative amount of Uredo rubigo-vera on different varieties of wheat*—Continued.

Localities and names of varieties of—	Bald or bearded.	Per cent of rustiness of varieties in— 1895. May 23–25.	1895. June 28–July 1.	1896. June 15–16.	1897. June 22–25.	Average.	Remarks.
WINTER WHEAT—continued.							
Russia—Continued.							
Swedish				50	50	60	
Theiss	Bearded			*45	*55	50	Hard wheat. *Mean of three grades.
Winter Ghirka	Bald			*53	*63	58	Hard-grained. *Mean of two grades.
Vysoko-Litovsk	do			*45	70	58	Hardy sort. *Mean of two grades.
Yx	Bearded			60	65	63	Hard-grained and hardy sort.
SPRING WHEATS.							
			June 21–23	June 29–30			
North Dakota:							
Glyndon No. 669	Bald		70	50		60	
Glyndon No. 673	do		60	60		60	
Glyndon No. 675	do		65	50		58	
Glyndon No. 747	do		65	60		63	
Glyndon No. 775	do		65	50		58	
McKissicks Fife	do		60	50		55	
Russia:							
Alsace	do		6	50	15	24	Hard wheat; some loose smut in 1895.
Arnautka	Bearded			15	5	10	A durum wheat.
Byelokoloska	Bald		3	60		32	Much loose smut in 1895.
Byelokoloska (Kursk)	do		5	60	10	25	Mildewed in 1895.
Chernuska	Bearded		3		5	4	A durum wheat. Mildewed in 1895.
Chernokoloska	do		...	25	5	15	A durum wheat.
Gharnovka	do		1	20		11	Badly mildewed in 1895.
Imperial	do		55	55		55	Hard wheat; some loose smut in 1895.
Krasnokoloska	Bald		20	50		35	Hard wheat; much mildewed in 1895.
Polish	Bearded		5	15		10	Flinty hard.
Saxonka	Bald		5	60		33	Hard wheat; mildewed in 1895.
Spring Ghirka (Ekaterinoslav).	do		15	65		40	Do.
Spring Ghirka (Samara)	do		5	60		33	Do.

A careful study of the table will show what a great variation there s in the ability of the same variety to resist or escape rust under dif'erent conditions. Some varieties that were almost rust free in 1895 vere badly rusted in 1896 and 1897, while others rusted less during the ast two years than in 1895. Another important conclusion to be drawn rom the experiments is that no ordinary variety of wheat is absolutely ust proof. Even the variety Einkorn above mentioned, which is not eally a true wheat, succumbed to the stem rust (*P. graminis*) in 1896. Nevertheless the fact remains that some varieties are better able to scape or resist rust than others under the same conditions and in the ame locality, and that some are quite resistant, at least comparatively peaking, in all localities and under all conditions, and it behooves the rower to know these varieties.

Characteristics of wheats resistant to orange leaf rust.—This is a subect of great interest and has already been discussed to some extent by

lifferent writers. So far as the ordinary wheats are concerned, the esistant varieties are as a rule somewhat dwarfed, are close and compact, and stool but little. The leaves, comparatively few in number, are stiff, narrow, and erect, with a more or less tough, dry cuticle, often with a glaucous or waxy surface; heads compact and narrow; and grains hard, red, small, and heavy.[1] In other words, the characteristics of these wheats are about the same as those of the wheats of semiarid regions. This is a fact of much significance, being a further argument hat more attention should be given to the cultivation of varieties par- icularly adapted to the black soils and climate of dry steppes, such as hose successfully grown in southeastern Russia, parts of Siberia, and n our own States of the Plains. Fortunately such varieties produce he finest grain and most nutritious flour known, and are usually hardy, lrought-resisting sorts. However, under the influence of certain con- litions of climate or locality, even these varieties, as above suggested, are likely to prove capricious as regards freedom from rust. In fact, no matter what the other conditions, every variety will rust, even con- siderably, if it matures late, and for this reason nearly all the hard Russian varieties mentioned in Table 3 rusted considerably. Early naturity is therefore another important quality. For rust freedom and or other purposes an early-maturing, hard, red, frost-resistant, and lrought-resistant winter sort is the ideal one for the greater portion of our wheat region.

The foregoing remarks apply only to the varieties of *Triticum vulgare* and to some extent perhaps to those of *T. compactum*. But the varie- ies that are almost rust proof, as shown by the table, belong mostly to he subspecies *T. durum* and *T. turgidum*, though a few of them belong o *T. dicoccum*, *T. monococcum*, and *T. polonicum*. Those of the first wo subspecies, called respectively durums and poulards, although very rich in gluten content, are seldom used in bread making, on account of coarseness and hardness of the grain and the dark color of he flour produced. They are extensively used, however, in the manu- facture of certain pastries and macaroni. Much of the latter is made n this country, and the cultivation of such wheats should be encour- aged. As these wheats are natives of hot, dry countries, they ought o do well, it seems, in the southern part of the Great Plains. If they could be matured sufficiently early (which was not possible in the experiments by this Department) they would certainly be very free from orange leaf rust, which seems to be especially bad in the South.

It will be seen that only a few of Farrer's crossbreds are included in he table. The chief reason for this is that those not included simply vinterkilled before the conclusion of the three years' experiments, and he amount of seed obtained being exhausted, they could not be tried urther. However, nearly all the crosses showed evidence of their

[1] Varieties resistant to this rust are also often bearded; therefore in the second column of Table 3, it is indicated whether varieties are bearded or bald.

high breeding and careful selection and some proved to be quite rust resistant, but as most of them were unfixed crossbreds their rust resistance could be fairly determined only by several years' trial and careful elimination of the most rust liable and less hardy plants. As shown by the table, it was found that almost invariably selections from the sporting progeny of unfixed crosses of bald and bearded varieties produced in the following years plants which showed that the bearded sorts are much more resistant to rust than the bald.

In addition to the experiments made by the writer, several were made in cooperation with the Department by persons in different States, the object being to test a few of the same varieties in different localities to determine their rust resistance and adaptability to such regions. Owing to various causes, chiefly lateness of seeding and drought, many of the experiments were entire failures, and in some cases the occurrence of rust was not carefully recorded. Only four were reported upon, these having been carried on by Prof. R. C. Kedzie, at the Michigan Agricultural College in 1896; Mr. B. F. Snyder, at Liberty, Indiana, in 1896; Mr. J. E. Payne, superintendent of the Rainbelt Experiment Station, at Cheyenne Wells, Colorado, in 1897; and by Mr. S. I. Wilkin, at Bow Creek, Kansas, in 1897. The following table gives a summary of the four reports:

TABLE 4.—*Report on Uredo rubigo-vera on wheat tested in four localities.*

Names of varieties.	Bald or bearded.	Wheat grown at— Agricultural College, Michigan, 1896.	Liberty, Indiana, 1896. Winter sown.	Liberty, Indiana, 1896. Spring sown.	Cheyenne Wells, Colorado, 1897.	Bow Creek Kansas, 1897.
Banatka	Bearded	Slightly rusted.		Badly rusted		
Barletta	Bald					
Bearded Winter	Bearded				A failure	Nearly every blade rusted.
Budapest				Some rusted	No rust	
Chernokoloska	Bearded	Slightly rusted.				
Chubut	do			Some rusted		
Crimean	do	A failure	A failure	Badly rusted		
Genealogic Red					do	
Genealogic White					do	60 per cent rusted.
Gray Winter		Slightly rusted.	A failure			
Imperial	Bearded					
Kusavka		Much rusted				
Little Head	Bald		A failure	Badly rusted		
Melka	do		do	do		
Red Bearded	Bearded	Slightly rusted.				
Red Ghirka			A failure		A failure	Every blade rusted.
Red Winter	Bald			Badly rusted	No rust	75 per cent rusted.
Theiss	Bearded	A failure		do	No rust	80 per cent rusted.
White Kalinovka	do			do		
Winter Ghirka	Bald		A failure		No rust	30 per cent rusted.
Yx	Bearded				do	

Although this table gives but little information, still it is of some *interest in connection with Table 3.*

No rust was observed at Cheyenne Wells, either on the varieties from ıe Department or on any others tested at that station in 1897. The :mosphere at that place is exceedingly dry, but nevertheless attempts re being made to grow crops without irrigation.

The field experiments described have thrown much light on another oblem of even greater practical importance than the liability of arieties to orange leaf rust; that is, the comparative adaptability of ıe different sorts and varieties to the conditions of our wheat regions. owever, this question does not properly belong in these pages and onsequently must be discussed in another place.

Besides the experiments above reported, certain observations have en made by others in this country on the rust resistance of different urieties of wheat, especially as regards the orange leaf rust, and a w will be mentioned here. According to Pammel (55, p. 500), the llowing varieties were badly rusted at the Iowa Experiment Station 1889: Fife, Black Sea, White Fife, Manitoba Fife, Golden Globe, and st Nation. Velvet Chaff and Blue Stem were slightly rusted, but skatchewan "showed little tendency to rust." He also states that 1890 all the spring wheat was more or less severely injured by rust, ıd that some of the varieties were entirely worthless, but that rust d but little injury to the following winter wheats: Turkish Wheat, olden Cross, Red Fultz, Ontario, New Monarch, Fulcaster, and Deitz ongberry. "The Turkish Wheat yielded 24 bushels."

Latta (45, p. 87) in 1892 reported, by percentages, the proportion of alks rusted in various sorts at the Indiana Agricultural Experiment ation, and named Jones Winter Fife and Willitts as being rusted 0 per cent and Early Amber as rusted only 10 per cent. Latta and es (46, p. 62) in 1894 found in the same way that 100 per cent of the alks of the following varieties were rusted: Fulcaster, Velvet Chaff hite bearded), Red Clawson, Rochester Red, Beal, Johnson, Willitts, ones American Bronze, New Monarch, and Early Genesee Giant; but ıly 20 per cent of the stalks of Ohio Blue Stem and Nigger were sted. These estimates of course do not give the actual degree of stiness. In 1892 Georgeson, Burtis, and Shelton (36, pp. 14–50) pub-hed notes on rustiness of over 200 varieties grown at the Kansas gricultural Experiment Station farm. The varieties which remained iite free from rust were Arnolds Hybrid, Currell, Oregon Club, and berian. Those "very badly rusted" were Centennial, Red Fultz, oscoe, Walker, Wayne County Select, and Wintergreen.

Prof. W. M. Hays has been doing much work for several years in eeding and improving wheat varieties at the Minnesota Agricultural xperiment Station, and during that time has made notes on the degree rustiness of different sorts. He has kindly given the writer permis-on to use some of his notes for the year 1897, which are as follows:[1] ıe highest per cent of rustiness, according to these notes, was 35 in se of Ladoga and the lowest 7 in the case of Glyndon No. 761. The

The percentages of rustiness are in all cases means of two estimates made by ofessor Hays and an assistant.

varieties rusted 8 per cent and under are Haynes Blue Stem,[1] Risting Fife, Glyndon No. 761,[2] and Haynes Blue Stem x Glyndon No. 761 those rusted 20 per cent and over are Rio Grande, Preston, Percy Countess, Ladoga, Dawn, Alpha, and Progress. The last seven, which were most rusted of all the varieties, are Professor Saunders's new crossbreds sent from Canada.

Some observations made in the Southern States are of special interest, because of the usual abundance of orange leaf rust in that region. Tracy (68, pp. 23-25; 69, pp. 44-46) writes that the varieties Defiance and Beloturka, received from Australia, were strongly rust resistant in Mississippi and promise well for that region. Canning Downs received at the same time, winterkilled. Twelve varieties obtained from England ripened very late and were almost destroyed by rust. Two varieties from France, White Naples and Rieti, made very good yields. In Louisiana, where rust is very abundant, Stubbs (66, pp. 556-561) tested quite a number of varieties at Calhoun and Baton Rouge, most of them having been obtained from California. At Baton Rouge all the varieties failed completely. At Calhoun the following varieties were badly damaged by rust:

Four-rowed Imported Winter.	Holburn Wonder.
Red Wheat Gold Finder.	Thuring Row.
Halletts Red Winter.	Halletts Genealogic.
Hundred Fold.	Spauldings Prolific.
Arizona Indian.	Mammoth.
Carters Queen.	Hybrid Lamed.
Common March.	Egyptian.

Those entirely free from rust or only slightly affected were—

Indian Three Months.	California Spring.
Molds White Winter.	Winter Genoese.
Russian Red Bearded.	Ghirka.
Fulcaster.	Harris.
Big Long Bearded Club Brenner.	Diehl Mediterranean.
Sibleys No. 1.	White Russian.
Mediterranean.	White Boughton.
Red Russian.	Golden Cross.
Purple Straw.	Tuscan Island.

According to Kellner (41a, pp. 138-143), out of 151 varieties of wheat and spelt tested at the California Agricultural Experiment Station in 1892, only the following were practically rust free: Arizona Indian, Big Long Bearded Club, Blue Grass, F. Gates, Missogen, Nicaragua, Russian Durum, Russian Red Bearded, Red Sonora, Sicilian, Solid Straw Poulard, White Crimean, and Red Emmer.

In Australia the subject of rust resistance has, as already stated been investigated more, or at least by a greater number of investigators, than in any other country. Several elaborate series of such experiments have been made with different varieties and these have

[1] In duplicate plats rusted as high as 10 per cent.
[2] In duplicate plat rusted 11 per cent.

been reported by Pearson (57 and 58), McAlpine (51 and 52), Shelton (62 and 63), Lowrie (48 and 49), and others. It is impracticable to quote results from these different writers, but it will perhaps suffice to give the following list of varieties, which the last International Conference on Rust in Wheat[1] agreed upon as likely to be freest from rust in Australia and at the same time more or less desirable in other respects:

(1) *Rust-resistant varieties:*

Wards Prolific.	Marshalls No. 3.
Marshalls No. 8.	Australian Wonder.
Robins Rust-resistant.	

For cooler districts Defiance wheats, such as—

Wheatons Rust-resistant.	Blounts Lambrigg.
Pringles Defiance.	Tunnack.
Smiths Nonpareil.	

For cooler and moister districts Fife wheats, such as—

Improved Fife.	Hornblende.

(2) *Varieties escaping rust on account of early ripening:*

Allora Spring.	Budds Early.
Early Para.	Canning Downs.
Early Baart.	Rust-resistant.

(3) *Prolific and moderately rust-resistant varieties:*

Talavera.	White Lammas.
Leaks.	

During 1893 and 1894 Maddox (50, pp. 14–23) made observations at Eastfield, Tasmania, on the occurrence of rust on over two hundred varieties, including seventy-five or more crossbreds from Farrer. The following varieties and also 28 of Farrer's crossbreds were free or practically free from rust:

Wards Prolific (white).	Improved Fife.
Manitoba.	Fultz.
Wards Prolific (red).	Niagara.
Pringles No. 5.	Summer Club.
Bearded Herisson.	*Robins Rust-resistant.*
D'Arblays Hungarian.	Hornblende.
Bald Herisson.	Medeah.

The following varieties were free, or practically free from rust during 1893 and 1894:

Anglo-Australian.	Bega.
Blounts Fife.	Tourmaline.
White Fife.	Sicilian Square-headed Red.
Anglo-Canadian.	Saskatchewan.

[1] *Agr. Gaz.*, July, 1896, Vol. VII, pp. 438–442.

Two of Farrer's crosses and the following other varieties were rusted 50 per cent in 1894:

Bellevue Talavera.	Kings Jubilee
Quartz.	Clawson.
Hudsons Early Purple Straw.	Lazistan.
Rattling Jack.	Frames Early.
American Champion Head.	Red Tuscan.
Victorian Defiance.	High Grade.
White Naples.	Urtoba.
Early Baart.	Cape Wheat.
California Spring.	

The following varieties were rusted 75 per cent in 1893:

Square-head.	Red St. Laud.
Count Walderdorffs.	Frames Early.
Carters Stand-up.	Red Tuscan.
Boutchers Velvet.	High Grade.
Golden Drop.	Urtoba.
Bestehorns.	Cape Wheat.

In Sweden, according to Eriksson (31, pp. 340, 341), there was until recently but little difference noted in varieties as regards liability to brown rust (*Puccinia dispersa*), although his experiments showed great differences with respect to yellow rust (*P. glumarum*). However, in 1896, when the brown rust was unusually abundant and severe in that country, and when the teleutospores were for the first time observed on the stems (sheaths), at least to any great extent, there was a great difference in the amount of this rust on the different varieties. In another account of the rust that year (27, pp. 248–251) Eriksson divides the varieties tested into three classes, according to their degree of rustiness. Class 1 includes the varieties free from rust, at least as far as the sheaths are concerned; class 2 includes the varieties sparingly or considerably rusted; and class 3 includes those badly rusted. Examples of class 1 are—

Horsefords Pearl.	Michigan Bronze.
Scholeys Square-head.	Kinver Square-head.
Blé a Epi Carrè.	Count Walderdorffs.

Examples of class 3 are—

Frankenstein.	Manchester.
Grevenhagen.	Shireffs Square-head.
Hickling.	Blood Red.
Red Chaff Danzig.	Beselers Brown Thick-head.
Hungarian White.	White Club Spelt.

In India very little has been demonstrated concerning the liability of different varieties to rust, though various experiments with wheat have been conducted for many years in different provinces of that country. In the Central Province, where *P. rubigo-vera*, or "gerwa," as the natives

all it, is said to be the principal disease with which farmers have to ontend, the wheats generally regarded as rust proof are Mundia Pissi and Bansi, but the former is not a very marketable sort. At the Nagpur Experimental Farm experiments were made in 1895 (12, pp. 19–21) to test the comparative liability to rust of four varieties, including Mundia Pissi, and a similar series was planned in 1897 (13, pp. 22–24) with eight varieties, including Mundia Pissi and Bansi. As ut little rust occurred on any of these varieties experimented with, o conclusions could be drawn. Twenty-nine of Farrer's crosses were ried in 1897. The 26 of these that came to maturity were very late n ripening and rusted badly, though no other varieties were rusted. The rust, however, did not injure the grain.

A variety, supposed to be from America, was tested at the Cawnpore Experimental Farm in 1896 (37, pp. 22, 23) and remained entirely free rom rust, while the common sort, Muzaffarnagar, beside which it was grown, rusted here and on other fields of the farm. Judging from the lescription of the variety, however, it is probably not of American rigin, but a durum wheat, perhaps from the Mediterranean region.

Rust-free varieties for the United States.—Before leaving this subject ome suggestions may be given concerning rust-free varieties for this ountry. By reference to Table 3 it will be seen that after discarding ll that are not true bread-wheat varieties there is really little difference, so far as rust is concerned, in the sorts tested by this Department n 1896 and 1897 or in many of those tested in 1895. This is due chiefly, f not wholly, to the late seeding. Nevertheless, in case of most of the arieties in 1895, and even in the next two years, if the maximum of ustiness to be tolerated is raised considerably (to about 40 per cent), a umber of bread wheats remain fairly rust resistant.

Judging from all the experiments and observations discussed, the folowing varieties, already well known and good standard sorts in other lirections, may be recommended as likely to prove considerably resistnt to orange leaf rust in every part of this country, provided, of course, hat they are sown in time:

Winter wheats:

Turkey.	Rieti.
Mennonite.	Odessa.
Pringles No. 5.	Pringles Defiance.

Spring wheats:

Haynes Blue Stem.	Saskatchewan Fife.

The following varieties seem to be resistant, but have not yet been vell established as such:

Theiss.	Fulcaster.
Oregon Club.	Deitz Longberry.
Sonora.	Arnolds Hybrid.
Diehl Mediterranean.	California Spring.[1]

[1] Although according to name a spring variety, it withstands the winter quite well.

Some of the hardy prolific sorts not yet well known in this country but likely to be more or less rust resistant after thorough acclimation and selection, are—

Winter wheats:

Prolifero.	Winter Ghirka.
Banatka.	Budapest.
Red Winter.	Crimean.
Nashi.	Yx.
Tangarotto.	Bellevue Talavera.
Bearded Winter.	

Spring wheats:

Alsace.	Spring Ghirka.

Two varieties which are quite susceptible to rust, but which usually ripen early enough to escape the worst effects of it, are—

Early May.	Zimmerman.

Some others not quite so well known, but probably worthy of trial as rust-escaping sorts, are—

Early Baart.	Japanese No. 2.
Allora Spring.	Yemide.
Kathia.	Canning Downs.
Roseworthy.	

These last varieties, however, are not likely to withstand very severe winters, and are therefore best adapted to southern districts, where they may perhaps in time become acclimated. Yemide and Kathia are probably the most hardy of the six. As already stated, Canning Downs winterkilled in one trial even in Mississippi.

The following durum and poulard wheats adapted to hot districts and under most conditions extremely resistant to the orange leaf rust, are suggested as being well worthy of trial as macaroni wheats in the Southern States.

Arnautka.	Petanielle Noire de Nice.
Taganrog.	Gallands Hybrid.
Beloturka.	Chernuska.
Nicaragua.	Crotan.
Medeah.	Missogen.

Two varieties of the emmer and monococcum groups from Germany that are recommended for further trial as stock feed are—

Einkorn.	Black Velvet Compound Emmer.

These are very resistant to rust, Einkorn remaining absolutely proof against the orange leaf rust during two years when it was very severe.

Damage.—In previous publications (16 and 17, p. 497) the writer expressed his opinion that after all the orange leaf rust, as a rule, does very little, if any, damage to wheat, even during periods when it is quite abundant. Although further investigations have confirmed this belief, he is now inclined to think that occasionally, under certain

conditions and in certain localities, considerable injury may ensue if the rust occurs much in advance of harvest. In all instances, however, where the wheat is a total loss, which often occurs in such States as Kentucky, Indiana, Texas, Michigan, and Ohio, the black stem rust is found to be the chief, if not the only, rust present; and in all the writer's experience he has not met with a single well-authenticated case in this country where the leaf rust caused actual shriveling of the grain.[1]

In recent years botanists of all countries except England and Sweden seem to agree that *P. rubigo-vera* is not only the common rust, which is true, but also the one of economic importance, as will be seen by consulting the writings of Arthur (1), Bolley (7, pp. 13, 14), Barclay (5, Vol. XXX, pp. 46, 47), and Cobb (18, p. 34),[2] and in view of the limited amount of field work done it is natural that such an idea should prevail. The error arises from confusing the abundance of orange leaf rust every year with the destructive effects of black stem rust in certain years. Farmers, however, universally fear "black rust on the stems." It is significant in this connection that Barclay (5, Vol. XXX, p. 47), after admitting that the natives in India recognize the difference between "rolli" (*P. graminis*) and "rolla" (*P. rubigo-vera*), yet says that a "Zemindar" who sent him specimens stated that "rolla" is less destructive than "rolli."

Farrer (33, p. 36; 33*a*, pp. 163, 164) has for some time maintained that in Australia *P. rubigo-vera* does but little damage. McAlpine (51, pp. 27, 28; 52, p. 26) also seems to believe the damage is commonly done by *P. graminis*. The writer's experiments at Garrett Park, Md., afforded an excellent opportunity to test the matter thoroughly, *P. graminis* being entirely absent there in 1895, while *P. rubigo-vera* was about as abundant as it could well be. As shown in Table 3, a majority of the varieties were very much rusted, yet the very sorts rusted most produced perfectly plump grains. On the other hand, curiously enough, it is constantly maintained that wheat is badly damaged by rust in the Southern States and in nearly all cases the orange leaf rust is the one reported to be present. However, the matter should be looked into more carefully in that region. In several cases of complete destruction of the grain personally investigated by the writer in the southeastern part of Texas, *P. graminis* was undoubtedly the real cause.

[1] Barclay (5, Vol. XXX, pp. 4, 5) gives two instances in which he weighed the grains of samples of wheat affected with *P. rubigo-vera* received from different places in India, and found that those of one sample weighed one-sixth as much as correspondingly healthy ones and those of the other sample weighed one-half as much. However, nothing is said as to whether the healthy grains were of the same variety of wheat as the injured ones or whether *P. graminis* was not also present on the rusted specimens.

[2] It is admitted by Cobb that *P. graminis* perhaps did the damage to wheat in Australia in 1889, and that it may be the injurious species in some other years, as it is "a very vigorous rust."

Certain instances seem to show that occasionally, when this rust appears suddenly or unusually early in dry seasons, it is capable of doing some injury indirectly, either by preventing the leaves (its chief point of attack) from elaborating sufficient food material for the plant, or by causing too great transpiration through injury of the leaves, or in both ways. Galloway (35, pp. 445–452), in his article on leaf casting of *Pinus virginiana*, records important experiments, which show the increase of transpiration in rust-injured leaves of the pine. In the experiments at Manhattan, Kans., in 1897, the grain of many experimental varieties of wheat was considerably injured, and seemingly, in part, at least, by this rust. Just after the appearance of the rust in great abundance a dry period set in and continued until harvest. But even in this case *P. graminis* was also present in considerable quantity, and may really have caused the injury. Eriksson (27, pp. 245–248) claims that the first instance of any injurious occurrence of *P. dispersa* that he observed in Sweden was in the season of 1896, the first twenty days of June of this year being drier and hotter than any corresponding period in seven years.

Certain phenomena observed during the experiments at Garrett Park led the writer to think that in very wet seasons this rust may be actually of some benefit to the grain by preventing too much growth of the vegetative parts of the plant at the expense of the reproductive portions. Though many varieties produced shriveled grain in these experiments, those most severely affected with rust produced good grain. Little (47, p. 640), in his discussion of wheat "mildew" in England, also refers to this. He notes that "in the Fen districts, which suffer most from mildew, the prevalence of this spring rust (*Uredo rubigovera*) is believed to be rather beneficial than otherwise, as it reduces the excessive luxuriance, which is usually the result of a mild winter, and which is popularly supposed to make the wheat crop more liable to mildew."

ORANGE LEAF RUST OF RYE.

(*Puccinia rubigo-vera secalis*).

Physiological relations.—Although this rust strongly resembles the orange leaf rust of wheat, inoculation experiments have shown that there is not only no physiological connection between them, but that the orange leaf rust of rye can not, so far as the writer has yet determined, be transferred by inoculation to any grass, wild or cultivated, except *Secale montanum*. Experiments with the uredo of this rust were begun in the spring of 1896 with material which was kindly sent to the writer by Prof. F. S. Earle, of the Alabama Agricultural Experiment Station.

These experiments are summarized in the following table:

TABLE 5.—*Inoculation experiments with Uredo rubigo-vera secalis.*

Date of inoculation.	Place where experiments were made.	Origin of inoculating material.	Plant inoculated.	Period of incubation (days).	Result.
1896.					
May 20	Washington, D. C.	Rye	Rye	14	Successful.
Do	do	do	*Elymus canadensis*	14	Negative.
Do	do	do	*Elymus americanus*	14	Do.
Do	do	do	*Elymus virginicus*	14	Do.
Do	do	do	*Elymus condensatus*	14	Do.
Do	do	do	Wheat	14	Do.
Do	do	do	Japanese wheat	14	Do.
Do	do	do	Persian Red Spring wheat	14	Do.
Do	do	do	*Poa nemoralis*	14	Do.
Do	do	do	*Dactylis glomerata*	14	Do.
Do	do	do	*Hordeum murinum*	14	Do.
Do	do	do	Rye	11	Successful.
Do	do	do	Early Baart wheat	11	Negative.
Do	do	do	Oats	11	Do.
Do	do	do	*Poa pratensis*	11	Do.
May 27	do	do	Siberian rye	12	Successful.
Do	do	do	Wheat	12	Negative.
Do	do	do	Oats	12	Do.
Do	do	do	Barley	12	Do.
Dec. 21	do	do	Rye	16	Successful.
Do	do	do	Wheat	16	Negative.
Do	do	do	*Elymus americanus*	16	Do.
Do	do	do	Oats	16	Do.
Do	do	do	Barley	16	Do.
Do	do	do	*Kœleria cristata*	16	Do.
Do	do	do	*Poa pratensis*	16	Do.
Do	do	do	*Dactylis glomerata*	16	Do.
Do	do	do	Rye	9	Successful.
Do	do	do	Wheat	9	Negative.
Do	do	do	Rye	18	Successful.
Do	do	do	Wheat	18	Negative.
1897.					
Jan. 7	do	do	Rye	12	Successful.
Do	do	do	*Elymus virginicus*	12	Negative.
Do	do	do	*Dactylis glomerata*	12	Do.
Feb. 1	do	do	Rye	13	Successful.
Do	do	do	Barley	13	Negative.
Do	do	do	Wheat	13	Do.
Do	do	do	Oats	13	Do.
Do	do	do	*Dactylis glomerata*	13	Do.
Do	do	do	*Sporobolus asper*	13	Do.
Do	do	do	*Anthoxanthum odoratum*	13	Do
Do	do	do	*Phleum pratense*	13	Do.
Do	do	do	*Melica altissima*	13	Do.
Do	do	do	*Poa pratensis*	13	Do.
Do	do	do	*Poa nemoralis*	13	Do.
Do	do	do	*Elymus virginicus*	13	Do.
Do	do	do	*Festuca gigantea*	13	Do.
Do	do	do	Corn	13	Do.
Feb. 20	do	do	Rye	12	Successful.
Do	do	do	*Secale montanum*	12	Do.
Do	do	do	*Agropyron repens*	12	Negative.
Do	do	do	*Agropyron tenerum*	12	Do.
Do	do	do	*Triticum villosum*	12	Do.
Do	do	do	*Elymus canadensis*	12	Do.
Do	do	do	*Dactylis glomerata*	12	Do.
Mar. 30	do	do	Rye	33	Successful.
Do	do	do	*Agropyron caninum*	33	Negative.
Do	do	do	*Lolium perenne*	33	Do.
Nov. 8	Manhattan, Kans	do	Rye	9	Successful.
Do	do	do	Wheat	9	Negative.
Do	do	do	Barley	9	Do.
Do	do	do	*Agropyron tenerum*	9	Do.
Do	do	do	Rye	9	Successful.
1898.					
Jan. 5	Lincoln, Nebr	do	Rye	21	Do.
Do	do	do	*Elymus virginicus*	21	Negative.

The period of incubation for the orange leaf rust of rye is apparent a little longer than for the orange leaf rust of wheat, ranging fro eight to twelve days with ordinary greenhouse conditions. In a fe cases where, as the table shows, this period was extremely long, tin was allowed for the rust to infect other plants if it would, the rye itse having become infected at a much earlier date.

The experiments thus far made show that orange leaf rust of rye ma occur in this country on cultivated varieties of *Secale cereale* and on *montanum*. It was actually found on the latter host at Lincoln, Nebr November 16, 1897.

Occurrence and distribution.—As previously stated, this rust is alway present where rye is grown, but its distribution is limited in this cour try because rye is not extensively grown here. Like the correspondir rust of wheat, it seems to be more abundant in the Southern State According to Humphrey (40, pp. 228, 229) and Thaxter (67, p. 98), also occurs in considerable abundance in Massachusetts and Connect cut. What is said of its distribution in this country is true of it al in foreign countries, except in Russia and Germany, where rye is grow to a great extent, and where it is probably a much more prominei rust.

Wintering of the uredo.—In the Southern States this rust, like tl leaf rust of wheat, not only lives over, but propagates through tl winter in the uredo stage. As rye is rather hardy, the writer's opinic is that the rust readily passes the winter as a uredo in all parts of tl United States, but owing to the small extent to which the crop is grow he has not been able until very recently to demonstrate its ability to (so in any locality, and Humphrey (40, p. 229) failed to find any eviden that it does so in Massachusetts. However, in November, 1897, tl writer found the uredo in great abundance in a patch of volunteer ry at Lincoln, Nebr., and afterwards, in midwinter, it was seen in tl same place on green leaves. On April 15, 1898, it was still present i considerable quantity, but was confined entirely to the leaves of tl previous autumn's growth and had without question lived throug the winter, though the leaves were still somewhat green. Some of tl uredospores placed in water-drop cultures germinated, a few of the producing very long germ tubes. Two days afterwards, that is, Apr 17, the uredo was again found in considerable quantity several mil from the other locality in a large field of rye seeded for pasturag being, as before, confined entirely to the leaves of the previous autumn growth. In neither case was there any production of new spores, an yet the spring was so far advanced that there could be no questio about the continued growth of the rust. The weather was unusuall cold in November and December, the temperature falling to $-27\frac{1}{9}$ (on the 18th of the latter month at the State University, but on tl whole the winter was not particularly severe.

The uredo of this rust probably winters over in most other countri also, but in nearly all observations so far made by others concernin

.ie matter it is impossible to determine whether this rust or the leaf .ust of wheat is referred to.

The economical bearing of this subject is most important. A fact of much significance is that the leaf rusts of wheat and rye are the only ereal rusts that winter their uredos in this country and are at the ame time the only ones that can not be transferred by inoculations to ny other host except species of the same genera. The obvious infer-nce is that these rusts perpetuate themselves from year to year prin-ipally by means of their uredos, but that occasionally the teleutospores robably bridge over unusually severe winters, either by means of ome æcidium as yet unsuspected or by direct infection of the young lant early in the spring through the germinating sporidia. There is till the possibility, however, that other uredo hosts may be found. Of course if these three alternatives were absent these rusts could be eadily eradicated by the concerted action of farmers in keeping their arms rigidly clean of volunteer grain.

Liability of different varieties to this rust.—On account of so few orts of rye being grown in this country, no particular attention has een given to the subject of rust liability of varieties. However, it nay be said that all fields of rye, without exception, are usually more r less affected.

In the experiments at Salina a number of packages of spring rye ("yaritsa" in Russian), received from the region near Nerchinsk, Siberia, ere tested, some of them being planted in the autumn and some in he spring. All the plants were rusted, the rustiness ranging from 60 o 80 per cent.

Damage.—The damage to rye from this rust is very little, as a rule, s in the case of leaf rust of wheat. According to Humphrey (40, pp. 28, 229) and Thaxter (67, p. 98), it occasionally causes considerable njury in Massachusetts and Connecticut, and it is also said to be quite njurious at times in the Southern States. According to Prof. J. H. Connell, director of the Agricultural Experiment Station, College Sta-ion, Tex., rye in the experimental plats of the station is occasionally njured by this rust even in January.

CROWN RUST OF OATS.

(*Puccinia coronata* Corda.)

Physiological relations.—The fact that this rust occurs on oats only, nd that its appearance, both superficially and microscopically, is very ifferent from that of the black stem rust, together with the peculiar orm of its teleutospores, make it the most distinct of all the cereal usts. The uredospores are so much like those of the leaf rusts of wheat and rye, however, that when only these were present the writer ould not be certain that the crown rust and the leaf rusts did not xchange hosts until he determined the matter by inoculation. There

is evidence, too, that many identifications of cereal rusts have been ma simply at random. Though the crown rust of oats is recorded as occu ring on a great many wild grasses, the writer has made but two colle tions of rust on such grasses which he could demonstrate, even morphological grounds, to be this rust.

The writer has made more inoculation experiments with oat ru than with any of the other cereal rusts. The following table gives summary of his experiments with the crown rust:

TABLE 6.—*Inoculation experiments with Uredo coronata.*

Date of inoculation.	Place where experiments were made.	Origin of inoculating material.	Plant inoculated.	Period of incubation (days).	Result.
1896.					
Feb. 6	Washington, D. C.	Oats	Siberian oats	8	Successfu
Do.	do	do	Black Tartarian oats	8	Do.
Feb. 14	do	do	Siberian oats	10	Do.
Do.	do	do	Black Tartarian oats	10	Doubtful
Do.	do	do	Early Para wheat	10	Negative.
Do.	do	do	Siberian wheat	10	Do.
Do.	do	do	Siberian barley	10	Do.
Do.	do	do	Siberian rye	10	Do.
Do.	do	do	Nebraska White Prize corn	10	Do.
Feb. 24	do	do	*Hordeum murinum*	17	Only one two sp
Mar. 4	do	do	Siberian wheat	35	Negative
Do.	do	do	do	29	Do.
Do.	do	do	Siberian rye	35	Do.
Do.	do	do	do	29	Do.
Do.	do	do	Early Para wheat	35	Do.
Do.	do	do	do	29	Do.
Do.	do	do	Siberian barley	35	Do.
Do.	do	do	do	29	Do.
Do.	do	do	Corn	35	Do.
Do.	do	do	do	29	Do.
Do.	do	do	Rieti wheat	12	Do.
Do.	do	do	Siberian millet	12	Do.
Do.	do	do	Safeed wheat	12	Do.
Do.	do	do	Persian Red Spring wheat	12	Do.
Do.	do	do	Beloturka wheat	12	Do.
Do.	do	do	Shirosawa wheat	12	Do.
Do.	do	do	Persian Black barley	12	Do.
Do.	do	do	Rieti wheat	13	Do.
Mar. 11	do	do	Six-rowed barley	7	Do.
Do.	do	do	*Avena fatua*	7	Successfu
Do.	do	do	Hungarian White oats	7	Do.
Do.	do	do	Donka wheat	7	Negative.
Do.	do	do	Siberian oats	7	Successfu
Do.	do	do	Pied de Mouche oats	7	Do.
Do.	do	do	Chinese barley	7	Negative.
Do.	do	do	*Agrostis alba vulgaris*	7	Do.
Do.	do	do	*Dactylis glomerata*	7	Do.
Do.	do	do	*Elymus virginicus*	7	Do.
Do.	do	do	Nackter Kleiner Fahnen oats	7	Successfu
Mar. 12	do	do	Siberian millet	12	Negative.
Do.	do	do	Safeed wheat	14	Do.
Do.	do	do	Haffkani wheat	12	Do.
Do.	do	do	Etampes oats	12	Do.
Do.	do	do	Nebraska White Prize corn	12	Do.
Do.	do	do	Persian Black barley	12	Do.
Do.	do	do	*Dactylis glomerata*	12	Do.
Do.	do	do	Etampes oats	11	Successfu
Mar. 18	do	do	Late Danish oats	11	Do.
Mar. 30	do	do	*Hordeum murinum*	10	Do.
Apr. 6	do	do	*Avena pratensis*	10	Do.
Do.	do	do	*Koeleria cristata*	10	Negative.
Do.	do	do	*Phleum pratense*	10	Successfu
Apr. 9	do	do	*Bromus unioloides*	13	Negative.
Do.	do	do	*Agropyron repens maritimum* !	13	Do.
Do.	do	do	*Agrostis alba vulgaris*	19	Do.
Do.	do	do	*Lolium perenne*	13	Do.
Do.	do	do	*Dactylis glomerata*	13	Do.
Do.	do	do	*Koeleria cristata*	13	Do.
Apr. 11	do	do	*Avena pratensis*	9	Successfu
Apr. 17	do	do	Fentons Rust-Proof oats	15	Do.
Do.	do	do	*Avena pratensis*	15	Do.

TABLE 6.—*Inoculation experiments with Uredo coronata*—Continued.

Date of inoculation.	Place where experiments were made.	Origin of inoculating material.	Plant inoculated.	Period of incubation (days).	Result.
1896.					
Feb. 17	Washington, D. C	Oats	*Bromus unioloides*	15	Negative.
Do.	do	do	Oats	15	Successful.
Do.	do	do	*Hordeum jubatum*	15	Negative.
Do.	do	do	*Arrhenatherum elatius*	15	Do.
Do.	do	do	*Lolium perenne*	15	Do.
Do.	do	do	*Dactylis glomerata*	11	Successful.
Do.	do	do	Amurskii oats	11	Do.
Do.	do	do	*Aira cæspitosa*	11	Only one or two spots.
Do.	do	do	*Poa pratensis*	11	Negative.
Do.	do	do	*Holcus mollis*	11	Doubtful.
Do.	do	do	Fentons Rust Proof oats	11	Successful.
Do.	do	do	*Eatonia sp. indet*	11	Do.
Apr. 18	do	do	Ligowo oats	7	Do.
Do.	do	do	*Dactylis glomerata*	7	Do.
Do.	do	do	*Korleria cristata*	7	Do.
Do.	do	do	*Anthoxanthum odoratum*	7	Do.
Apr. 22	do	do	*Festuca sp. indet*	11	Do.
Do.	do	do	*Alopecurus alpestris*	11	Do.
Do.	do	do	*Phalaris arundinacea*	11	Do.
Do.	do	do	*Polypogon monspeliensis*	11	Do.
Do.	do	do	*Trisetum subspicatum*	11	Only one or two spots.
Do.	do	do	*Poa pratensis*	11	Negative.
Do.	do	do	*Sporobolus asper*	11	Do.
Do.	do	do	*Aira cæspitosa*	11	Do.
Do.	do	do	*Brizopyron siculum*	11	Doubtful.
Do.	do	do	*Andropogon halapense*	11	Negative.
May 1	do	do	Ligowo oats	14	Successful.
Do.	do	do	*Triticum spelta æstivum*	14	Negative.
Do.	do	do	*Sporobolus cryptandrus*	14	Do.
Do.	do	do	*Panicum crus-galli*	14	Do.
May 6	do	do	*Ammophila arundinacea*	12	Do.
May 7	do	do	Dun oats	13	Successful.
Do.	do	do	*Avena sterilis*	13	Only one or two spots.
Do.	do	do	*Phleum asperum*	13	Successful.
Do.	do	do	*Poa annua*	13	Only one or two spots.
Do.	do	do	*Ammophila arenaria*	13	Do.
Do.	do	do	*Eatonia dudleyi*	13	Negative.
Do.	do	do	*Brachypodium distachys*	13	Do.
Do.	do	do	*Schedonnardus paniculatus*	13	Do.
Do.	do	do	*Panicum crus-galli*	13	Do.
Do.	do	do	*Eleusine egyptiaca*	13	Do.
Do.	do	do	*Eragrostis purshii*	13	Do.
Do.	do	do	*Sporobolus cryptandrus*	13	Do.
Do.	do	do	*Eragrostis abyssinica*	13	Do.
May 20	do	do	*Triodia cuprea*	12	Do.
Sept. 23	Manhattan, Kans	do	Oats	7	Successful.
Dec. 15	Washington, D. C	do	do	11	Do.
Dec. 21	do	do	do	17	Do.
Do.	do	do	*Anthoxanthum odoratum*	17	Negative.
1897.					
Feb. 12	do	do	*Arrhenatherum elatius*	18	Do.
Mar. 30	do	do	Oats	12	Successful.
Do.	do	do	*Eatonia obtusata*	12	Negative.
1898.					
Mar. 12	Lincoln, Nebr	do	Oats	25	Successful.
Do.	do	do	*Phalaris caroliniana*	25	Negative.
Do.	do	do	*Agrostis alba vulgaris*	25	Do.
Do.	do	do	*Arrhenatherum elatius*	25	Do.

A peculiar feature of these experiments is that although the rust does not seem to actually occur on many native grasses, yet the cases of successful infections of grasses in the greenhouse are rather numerous. Aside from the fact that some of the grasses may yet be found to be hosts in nature, there are two possible explanations of this peculiarity: (1) The inoculations were made as a rule on young plants,

which, having less resistant constitutions, are always more susceptib to disease than older ones; and (2) as the experiments were made the greenhouse the conditions were, of course, somewhat more favorab to rust propagation than those outdoors. As to the condition of tl host, the matter was tested in a few cases by inoculating at a mo advanced age certain plants that had been successfully infected wh quite young, the result being that infections did not occur at all or we very slight and evidently took place with difficulty. In the experimen with the leaf rusts of wheat and rye young plants were also used hosts, but the results were quite different. The crown rust, it seem is not yet sharply limited in its adaptability to particular hosts.

The table shows that although rust from oats infected a number wild grasses, no case is recorded of an infection of oats from a wil grass; hence it has not been demonstrated that the crown rust of oa is equivalent to the rust of any wild grass, although it is of cour quite probable that the same rust occurs on several species of the gen Avena and perhaps on other grasses. In the writer's opinion the ide tity of a rust of any grass with that occurring on any cereal is n established until reverse infections have been produced.

Another important question that yet remains unsettled is wheth there is an æcidial host for this rust of oats in the United State True, an æcidium on a species of Rhamnus has been collected in number of places, but as yet no inoculation experiments have bee made with it, and it will require many to determine accurately tl status of the crown rust in this country.[1]

The usual incubation period to produce infections on oats in case inoculations with this rust is from seven to ten days, but to infect ce tain other plants, such as *Hordeum murinum* and *Dactylis glomerata*, longer time is required, and when plants are rather old scarcely an infection results.

From experiments so far made, only cultivated varieties of the fo lowing subspecies of *Avena sativa* can be considered to be hosts of th rust in the United States: *Avena sativa patula*, *A. sativa orientalis*, an *A. sativa nuda*.[2] Other species of Avena that will probably yet b found to act as hosts are *A. fatua*, *A. pratensis*, *A. hookeri*, and *A sterilis*. Of course there is the possibility also that this rust will b found to have several specialized forms in this country, as Eriksso (28, p. 302) has already found to be the case in Sweden.

Occurrence and distribution.—The crown rust in its distribution seem to be quite analogous to the leaf rust of wheat, and in that regard bot bear somewhat similar relations to the black stem rusts of the sam

[1] Since this bulletin was prepared the writer has made a number of inoculatio experiments with the æcidium of *Rhamnus lanceolata* at Lincoln, Nebr., which resulte in the infection of oats, *Phalaris caroliniana*, and *Arrhenatherum elatius*.

[2] *Phalaris caroliniana* and *Arrhenatherum elatius* must now also be included a probable hosts (see preceding footnote).

hosts. *It is the more common of the two oat rusts in the United States.* So far as locality is concerned, there seems to be little difference in its distribution, but compared with the stem rust it seems to be especially prevalent in the Atlantic and Southern coast States. Apparently it is not as constant in its occurrence from year to year as the leaf rust of wheat, though the writer is not certain of any instance where it was entirely absent during the entire summer. Although one of the most prominent rusts in the United States, it is, strange to say, so far as yet known, rather insignificant in most other countries. According to Barclay (5, Vol. XXX, p. 46), it does not occur on any cereal in India, but a variety, *P. coronata himalayensis*, occurs on *Brachypodium sylvaticum*. The writer has not been able to find any record of its occurrence in Australia, and although found on European oats, it is apparently not very abundant.

Wintering of the uredo.—Although the writer's opinion is that this rust passes the winter in the uredo stage in the warmer latitudes of the United States, there is as yet no good evidence that it does. A case where volunteer oats bore this rust in both the uredo and teleuto stages was called to the writer's attention by Mr. M. B. Waite, of this Division, the first week of March, 1894, at Washington, D. C. The uredospores were found to be in apparently good condition on leaves not yet dead. Uredospores of both crown and stem rusts of oats were observed on volunteer oats at Manhattan, Kans., up to November 2 of the season of 1896, but there was no opportunity of determining whether they lived longer.

Liability of different varieties to this rust.—There is not as much known regarding the liability of varieties of oats to rust as there is relative to liability of varieties of wheat. One reason for this is, probably, that there is less difference in the structure and physiological constitution of the former. In Australia, where the subject of liability of varieties to rust has received most attention, neither the oat crop nor rust of oats seem to be of much importance. However, the farmers of the United States and of northern Europe know quite well that certain varieties of oats, as well as of wheat, are more exempt from rust than others. In some parts of the country, especially in California, black oats is said to be freer from rust than the white oats, and in the North the White Russian is said to be quite rust resistant. Although this rust is quite abundant in the Southern States, a certain variety of oats, known most generally, perhaps, as Texas Rust Proof, is universally claimed to be rust resistant, but the writer has had no opportunity of personally determining this matter. When this variety is grown in the North, however, it invariably rusts and sometimes badly. As usual, in none of these reports of rust on oats is there any statement as to the species of rust that was present, though a matter of the utmost importance. According to Professor Hays's notes for 1897 on the varieties of oats grown at the Minnesota Experiment Station, Winter Turf, Siberian White, Black

Etampes, Black Houdan, and Houstons Silver White were rusted onl 7 to 10 per cent, and Black America, Rust Proof, Monarch, Whit Bedford, White Superior Scotch, and Centennial were rusted 27 to 3 per cent.

While conducting the field experiments on rust liability of varietie of wheat, the writer also tested a number of varieties of oats in th *same way during* the first two years, and as the crown rust was th only one present at Garrett Park and the principal one at Salina the experiments will be discussed under this head. The varieties o oats used in these experiments were obtained through the same source as were the wheats, although, of course, they were not obtained fron so many countries. They represent nearly all the cultivated subspe cies and varieties of *Avena sativa*. The results of the experiment are arranged in the following table, to which the explanations of Table also apply. The varieties were all sown in the spring at the usua time, although a few of them were winter sorts. The methods of seed ing, etc., employed were the same as in the case of the wheats.

TABLE 7.—*Uredo coronata on varieties of oats.*

Localities and names of varieties.	Subspecies.[1]	Per cent of rustiness at—		Average.	Remarks.
		Garrett Park, July 16, 1895.	Salina, June 30, 1896.		
North Dakota:					
Black Prolific	s	2	92	47	
Early White Russian	p	0	93	47	
Fentons Rust Proof	p	2	91	47	
Giant Side	s	3	91	47	
Giant Yellow	p	4	89	47	
Golden Giant Side	s	5	70	38	
Great Northern	p	1	91	46	
Lincoln	p	4	92	46	
Race Horse	p	3	[a]95	49	[a] Mean of two grades.
Tartarian	s	1	88	45	
Wide Awake	p	5	95	50	
Scotland:					
Barbachlow	p	7	90	49	
Black Tartarian	s	1	([b])	1	[b] Not planted in 1896.
Blainslie	p	5	94	50	
Dun	p	1	91	46	Either winter or spring va riety.
Early Angus	p	4	90	47	
Hamilton		0	90	48	
Hopetoun	p	5	90	48	
Long Fellow	p	5	97	51	
Potato	p	5	93	49	
Providence	p	5	85	45	
Sandy	p	1	96	49	
Tom Finlay	p	5	95	50	Same as White Polish.
Sweden:					
Black Tartarian	s	3	93	48	
Ligowo	p	2	60	31	
Svalöfs		3	93	48	
Germany:					
Anderbeck		11	97	54	
Angus	p	10	92	51	
Australian (Port Adelaide)	p	5	80	43	
Barbachlow		13	90	52	
Berwick	p	12	94	53	
Bestehorn		8	85	47	
Black Hungarian	s	12	92	52	
Black Nubian		10	93	52	

[1] *p* means panicled oats, *s* side oats, *n* naked oats, and refer, respectively, to the subspecies *patula*, *orientalis*, and *nuda* of *Avena sativa*.
[2] The reference marks call attention to notes in the last column.

TABLE 7.—*Uredo coronata on varieties of oats*—Continued.

Localities and names of varieties.	Subspecies.	Per cent of rustiness at— Garrett Park, July 16, 1895.	Salina, June 30, 1896.	Average.	Remarks.
rmany—Continued.					
Black side oats	s	10	90	50	
Black Tartarian (Hallett's pedigree).	s	8	85	47	
Black Tartarian side oats	s	10	90	50	
Brie	p	10	90	50	
Brown Panicled	p	10	90	50	
California Prolific	....	7	85	46	
Dun	p	12	95	54	
Early Schlesian	p	7	80	44	
Etampes	p	10	90	50	
Flandera	....	11	91	51	
Georgian	p	12	94	53	
Grey Winter	p	12	94	53	
Houdan	p	13	94	54	
Joanette	p	9	90	50	
Leutewitzer	....	40	91	66	
Ligowo	p	10	90	50	
Nackter Kleiner Fahnen	n	20	80	50	Small grain and short straw.
Nilson	....	20	95	58	
Pied de Mouche	....	10	85	48	
Podolia	p	5	92	49	
Probsteier	p	10	92	51	
Providence	....	5	94	50	
Riesen Fahnen	....	40	95	68	
Rousse Couronnée	p	12	91	52	
Rigenscher	p	10	90	50	
Sandy	p	10	90	50	
Siberian	....	12	95	54	
Swedish	....	40	94	67	
Thüringer	p	13	93	53	
Ueberfluss	....	12	93	53	
Victoria	....	8	85	45	
Waterloo	p	40	85	63	
White Australian	p	12	95	54	
White Canadian (Hallett's pedigree).	p	10	90	50	Same as Georgian oat
White Hungarian	s	8	70	39	
White Polish	p	12	90	51	
White Tartarian	s	5	92	49	
ssia:					
Amurskii	p	4	85	45	Very tall and heavy straw.
Anderbeck	....	5	93	49	*Mean of two grades.
Australian	p	3	92	48	
Australian (Grodno)	p	4	92	48	
Cherull	....	4	90	47	*Late, but drought resistant.*
Danois	....	3	90	47	
Double-fruited	....	5	92	49	
Grey Winter	p	4	90	47	
Kurak	....	5	94	50	
Nagii	n	3	92	48	*Rather large grains.*
Odnogrivii Byelii	s	1	85	43	
Odnogrivii Chernii	s	4	93	49	
Orlovskii	....	3	90	47	
Probsteier	p	5	94	50	
Race Horse	p	4	94	49	
Shatilovskii	....	5	*95	50	*Mean of two grades.
Tsobiliye	....	4	92	48	
Ueberfluss	....	3	91	47	
Victoria	....	4	*90	47	Do.
Welcome	....	1	80	41	
White Canadian	....	1	80	41	Same as Georgian.
White Danish	p	4	91	48	
Zholannuii	....	5	92	49	
ly:					
Bianca di Canada	....	3	90	47	
Casertana Grossa	....	1	88	45	
Comuno di Viterbo	p	4	92	48	
Di Ruvo di Puglia	p	2	85	44	
Gentile Prima Verite del Umbria.	....	4	90	47	A very early variety.
Gigante a Grappola	....	3	90	47	
Nera di Tartara	s	5	96	51	
Precoce Detta Nuova Zelanda.	....	5	93	49	
Tardiva Danese	....	5	04	50	
Veneziana	....	5	96	51	

TABLE 7.—*Uredo coronata on varieties of oats*—Continued.

Localities and names of varieties.	Subspecies.	Per cent of rustiness at—		Average.	*Remarks.*
		Garrett Park, July 16, 1895.	Salina June 30, 1896.		
France:					
Belgian Black Winter		2	93	48	
Black Hungarian	s	3	95	49	
D'Etampes	p	2	94	48	A black chaff sort.
Grey Houdan	p	3	95	49	
Grey Winter	p	1	88	45	
Jaune de Flandre	p	3	90	47	The Flemish oat.
Jaunette	p	3	92	48	Short straw.
Noire de Brie	p	1	88	45	
Rousse Couronnée	p	4	92	48	
White Hungarian	s	3	92	48	
Siberia:					
Siberian (Nerchinsk)		(1)	70	70	1 Not planted in 1895.
Siberian No. 7		(1)	60	60	Do.
Spain:					
Civada Blanca Granja de Barcelona.	p	0	95	95	
Portugal:					
Abrantes	p	1	88	45	

There was little difference in the amount of rust on different varieties during the second season, all being very badly affected. As the black stem rust also was present, it was very difficult to grade, even approximately, the amount of crown rust alone. It is believed that had the varieties been sown quite early in the case of the experiment at Garrett Park many of them would have escaped entirely, as the rust did not appear until very near harvest time, and only four varieties were rusted as much as 40 per cent. On the whole, the two years' experiments do not show much difference in the comparative liability of varieties of oats to the crown rust.

Damage.—The writer knows of no instance where it could be proved that this rust caused any really serious damage to oats, under ordinary conditions, when the black stem rust was not also present; but nevertheless it is quite possible that it may occasionally cause considerable injury. In any event it seems to be of more economic importance in this than in most other countries.

BLACK STEM RUST OF WHEAT.

(*Puccinia graminis tritici* Eriks. and Henn.).

Puccinia graminis has always served as a convenient species in which to include such grass rusts as show no particular morphological individuality, but which resemble this species, and as a result it is credited with more host plants than any other rust. The writer has found at least 38 different grasses given as hosts for this rust in America, and Eriksson states (31, p. 119) that 105 are recorded in the herbarium of the division of plant physiology of the experiment station at Stockholm as hosts for this species in Sweden. Nearly all such identifications are of little value from an economic standpoint, many of them are wrong morphologically, and some of them are little better than guesswork. Errors in identification often arise from the fact that the specimens show but one stage of the rust, usually the uredo stage.

The number of host plants has been considerably reduced in recent years by the separation of a number of new species, and also by more correct identifications. Some of the new species occurring in this country are *P. amphigena* Diet., *P. subnitens* Diet., *P. distichlidis* Ell. and Ever., *P. agropyri* Ell. and Ever., and *P. jubata* Ell. and Barth., but whether these are all good species the writer is not yet prepared to say. The last one, however, he believes is not.[1]

Physiological relations.—Long before the writer's inoculation experiments were begun he often noticed, as doubtless others have also, a considerable difference between the general appearance of the black stem rust of wheat and of oats. In fact the uredo stages on the two hosts, at least on the leaves, appear to differ from each other more than the uredo stages of *P. rubigo-vera* and *P. coronata*. The sori are longer, larger, and seemingly a little darker on oats than on wheat, and usually there is proportionally more of the uredo present on the former than on the latter, though this latter feature is quite variable. Of course such differences may be due to differences in constitution of the host plants, but this is not necessarily so, for the leaf rust and crown rust on the same hosts behave differently.

Believing such work would be of particular interest, the writer inaugurated some inoculation experiments with this widely distributed rust species, the experiments with the form on oats being started sooner and carried on to a greater extent than those with the form on wheat, which latter, on account of lack of inoculating material, were not begun until April 20, 1896. The sources of inoculating material were *Uredo graminis* of wheat, kindly sent in by Prof. R. H. Price, April 14, 1896, from the Texas Agricultural College farm, and barberry rust, furnished through the kindness of Prof. C. F. Wheeler, May 9 and 14, 1896, from the Michigan Agricultural College. These experiments are very incomplete, but are still under way. The following table gives a summary of the work so far done:

TABLE 8.—*Inoculation experiments with Uredo graminis tritici and Æcidium berberidis.*

Date of inoculation.	Place where experiments were made.	Origin of inoculating material.	Plant inoculated.	Period of incubation (days).	Result.
1896.					
May 1	Washington, D. C.	Wheat	Australian Glory wheat	11	Only one or two spots.
Do	do	do	Shiresawa wheat	11	Negative.
Do	do	do	Ligowo oats	11	Do.
May 9	do	do	Wheat	11	Successful.
Do	do	do	Blounts Lambrigg wheat x Hornblende.	11	Only one or two spots.
Do	do	do	Wheat	11	Successful.
Do	do	do	Banatka wheat	11	Do.
Do	do	do	Wheat	11	Do.
Do	do	do	Oats	11	Negative.
Do	do	do	do	11	Do.
May 20	do	do	Wheat	12	Successful.

[1] More recent experiments made by the writer show conclusively that *P. jubata* is not only the same as *P. graminis*, but is identical with the form *tritici* of wheat and barley.

TABLE 8.—*Inoculation experiments with Uredo graminis tritici and Æcidium berberidis*—Continued.

Date of inoculation.	Place where experiments were made.	Origin of inoculating material.	Plant inoculated.	Period of incubation (days).	Result.
1896.					
May 20	Washington, D.C	Wheat	Oats	12	Negative
Do	do	do	Wards Prolific wheat	12	Successfu
May 27	do	*Berberis vulgaris.*	*Persian Red Spring wheat*	18	Negative
Do	do	do	Ligowo oats	18	Do.
Do	do	do	Wheat	18	Do.
Do	do	do	*Berberis vulgaris*	18	Do.
Do	do	do	*Berberis thunbergii*	15	Do.
Do	do	Wheat	Wheat	14	Successfu
Do	do	do	do	14	Do.
Do	do	do	Barley	14	Do.
Do	do	do	do	14	Do.
Do	do	do	*Hordeum murinum*	14	Do.
Do	do	do	*Holcus mollis*	14	Negative.
Do	do	do	*Agrostis alba vulgaris*	14	Do.
Do	do	do	*Phleum pratense*	14	Do.
Do	do	do	*Koeleria cristata*	14	Successfu
Do	do	do	*Lolium perenne*	14	Negative
Do	do	do	Oats	14	Do.
Do	do	do	do	14	Do.
Do	do	do	*Dactylis glomerata*	14	Do.
Do	do	do	Rye	14	Do.
Do	do	*Berberis vulgaris.*	Barley	13	Successful
Do	do	do	Rye	13	Only one two spot
Do	do	do	Wheat	13	Negative.
Do	do	do	do	13	Do.
Do	do	do	Oats	13	Do.
Sept. 26	Manhattan, Kans	Wheat	Wheat	7	Successful
Dec. 21	Washington, D.C	Barley	Barley	18	Negative.
Do	do	do	Rye	18	Do.
Do	do	do	Oats	18	Do
Do	do	do	Wheat	18	Do.
Do	do	do	Corn	18	Do.
Dec. 24	do	Wheat	Wheat	9	Only one two spot
Do	do	do	Barley	9	Do.
Dec. 30	do	Barley	Wheat	13	Successful
Do	do	do	Barley	13	Do.
Do	do	Wheat	Wheat	15	Only one two spot
Do	do	do	Barley	15	Do.
1897					
Jan. 9	do	do	Wheat	10	Do.
Do	do	do	Kastamuni wheat	10	Successful
Do	do	do	Taganrog wheat	10	Do.
Do	do	do	Missogen wheat	10	Do.
Do	do	do	Rye	10	Negative.
Do	do	do	Barley	10	Do.
Do	do	do	Oats	10	Doubtful.
Do	do	do	do	10	Do.
Do	do	do	*Sporobolus asper*	10	Negative.
Do	do	do	*Phleum pratense*	10	Do.
Do	do	do	*Festuca gigantea*	10	Successful
Do	do	do	*Elymus virginicus*	10	Do.
Jan. 22	do	do	Wheat	11	Doubtful.
Do	do	do	Missogen wheat	11	Successful
Do	do	do	Rye	11	Negative.
Do	do	do	Barley	11	Do.
Do	do	do	Corn	11	Do.
Do	do	do	*Melica altissima*	11	Do.
Do	do	do	*Anthoxanthum odoratum*	11	Do.
Do	do	do	*Poa nemoralis*	11	Do.
Do	do	do	*Poa pratensis*	11	Do.
Do	do	do	*Agropyron spicatum*	11	Do.
Do	do	do	*Agropyron richardsoni*	11	Successful
Do	do	do	*Dactylis glomerata*	11	Do.
Do	do	do	*Elymus virginicus*	11	Do.
Feb. 1	do	do	Wheat	11	Only one two spot
Do	do	do	Barley	11	Negative.
Do	do	do	Oats	11	Do.
Feb. 12	do	do	*Dactylis glomerata*	18	Only one two spot
Feb. 13	do	do	Wheat	12	Negative.
Do	do	do	Taganrog wheat	12	Successful

TABLE 8.—*Inoculation experiments with Uredo graminis tritici and Æcidium berberidis*—Continued.

Date of inoculation.	Place where experiments were made.	Origin of inoculating material.	Plant inoculated.	Period of incubation (days).	Result.
1897.					
Feb. 13	Washington, D. C	Wheat	Missogen wheat	12	Successful.
Do	do	do	Barley	12	Only one or two spots.
Mar. 16	do	do	Wheat	16	Negative.
Do	do	do	Rye	16	Do.
Do	do	do	Barley	16	Do.
Do	do	do	Wheat	16	Do.
Do	do	do	do	16	Do.
Do	do	do	Akavemidashi wheat	16	Successful.
Do	do	do	do	16	Do.
Mar. 30	do	do	Einkorn (*Triticum monococcum*)	13	Do.
Do	do	do	*Elymus virginicus*	13	Negative.
Aug. 16	Stillwater, Okla	*Agropyron tenerum.*	Wheat	12	Only one or two spots.
Aug. 23	do	do	do	13	Negative.
Sept. 7	Manhattan, Kans	Wheat	do	8	Only one or two spots.
Do	do	do	Barley	8	Successful.
Do	do	do	Oats	8	Doubtful.
Sept. 13	do	Barley	Barley	10	Successful.
Oct. 5	do	*Hordeum jubatum.*	Rye	11	Negative.
Do	do	do	Wheat	11	Successful.
Do	do	do	Barley	11	Do.
Do	do	do	Oats	11	Negative.
Do	do	do	*Arrhenatherum elatius*	11	Do.
Do	do	do	*Triticum villosum*	11	Do.
Do	do	do	*Dactylis glomerata*	11	Do.
Oct. 14	do	do	Wheat	11	Successful.
Do	do	do	Barley	11	Do.
Do	do	do	Corn	11	Negative.
Oct. 21	do	Barley	Wheat	16	Doubtful.
Do	do	do	Barley	16	Only one or two spots.
Do	do	do	*Hordeum nodosum*	16	Negative.
Nov. 6	do	*Hordeum jubatum.*	Wheat	6	Successful.
Nov. 12	do	do	Wheat	11	Successful.
Do	do	do	Barley	11	Only one or two spots.
Do	do	do	Rye	11	Negative.
Do	do	do	Oats	11	Do.
Do	do	do	*Hordeum nodosum*	11	Do.
1898.					
Jan. 5	Lincoln, Nebr	*Elymus canadensis glaucifolius.*	Wheat	21	Successful.
Do	do	do	Barley	21	Do.
Do	do	do	Oats	21	Negative.
Do	do	do	Rye	21	Do.
Do	do	do	*Agropyron richardsoni*	21	Do.
Jan. 24	do	Wheat	Wheat	10	Successful.
Do	do	do	Barley	10	Do.
Feb. 11	do	*Elymus canadensis glaucifolius.*	Wheat	14	Do.
Do	do	do	Barley	14	Do.
Do	do	do	Rye	14	Negative.
Do	do	do	Oats	14	Do.
Do	do	do	*Elymus canadensis glaucifolius*	14	Successful.
Do	do	do	*Elymus virginicus*	14	Negative.
Do	do	do	*Agropyron tenerum*	14	Do.
Do	do	do	*Agropyron spicatum*	14	Do.
Do	do	do	*Elymus hirsutiglumis*	14	Do.
Do	do	do	*Elymus virginicus muticus*	14	Do.
Do	do	do	*Dactylis glomerata*	14	Do.
Do	do	do	*Agrostis alba vulgaris*	14	Do.
Feb. 21	do	do	*Elymus canadensis*	7	Successful.
Feb. 25	do	do	*Hordeum jubatum*	11	Do.
Feb. 28	do	do	Wheat	9	Do.

The results above given show that as a rule this rust form passes readily from wheat to barley and from barley to wheat, the exceptions not being more numerous than the failures from wheat to wheat, and such exceptions were probably generally caused by the presence of mildew or some other unusual condition. Indeed, it usually seemed that the transfers from wheat to barley and from barley to wheat, especially the latter, resulted more easily than did transfers from wheat to wheat or from barley to barley. As shown by the writer's investigations, it is the only cereal rust that readily infects more than one of the five cereals. In a few instances there were apparently slight infections of oats, but it was evident, if they were not accidental from *Uredo graminis* of oats, that the infections took place with difficulty.

One interesting feature of the experiments is that although the barberry rust in one set of experiments readily infected barley, it failed to infect wheat or oats and produced but one spot on rye. If the barberry rust was originally produced by the sporidia of teleutospores from wheat, which is not known, the failure to infect oats would be in accord with Eriksson's experiments (20, pp. 304, 305; 29, pp. 200–202), which showed that rust of barberry would infect only that cereal the rust form of which originally produced the barberry rust. On the other hand, the fact that it also failed to infect wheat, and infected rye but slightly, can not be thus explained; and this, with a few other peculiar results obtained, has led the writer to suspect that in this country there may be two distinct forms of the black stem rust on barley, one of which also infects rye but not wheat, and the other wheat but not rye. Like barley, *Hordeum jubatum* seems to also act as a host for both forms. Similarly peculiar results were obtained with certain other wild grasses and need to be further investigated.

As previously stated, the leaf rust seemed to infect the true bread wheats more readily than it did the durums and poulards, but in these experiments the reverse was true, the stem rust infecting durums and poulards more easily than it did the bread wheats. Moreover, larger and darker sori seemed to be formed on the durums and poulards than on the other wheats (Pl. IV, fig. 18)—an interesting fact in connection with the subject of rust resistance of varieties.

For the inoculations from the wild grasses *Hordeum jubatum*, *Agropyron tenerum*, and *Elymus canadensis glaucifolius*, material was of course obtained in the field on these hosts. Two rusts are found on *A. tenerum*, both of which seem to produce the same sort of sori on wheat, but only one is believed to be *P. graminis*. The spore forms were quite different.

Under ordinary greenhouse conditions the period of incubation for this rust in the uredo ranges from eight to twelve days. Under dates of September 26, 1896, November 6, 1897, and February 21, 1898, the shorter periods noted include only the time until signs of rust appeared, the epidermis not being broken until one or two days afterwards.

From experiments and observations so far made, the following may

be considered as established hosts for the black stem rust of wheat in this country: *Triticum vulgare*, *T. compactum*, *T. turgidum*, *T. durum*, and *Hordeum vulgare*—cultivated varieties, and *T. monococcum*, *T. polonicum*, and *H. jubatum.*

It is almost certain that the following species also act as hosts for this rust form: *Triticum spelta* and *T. dicoccum*—cultivated varieties, and *Agropyron richardsoni*, *A. tenerum*, *Elymus canadensis*, and *E. canadensis glaucifolius.*

Occurrence and distribution.—As to the occurrence of this rust in the United States, little need be added to what has already been said. A fact of particular importance is that the stem rust, unlike the leaf rust, is not constant in occurrence, but will occasionally miss one or two years in five or six, depending, however, pretty much upon the locality. Although sometimes very destructive in any part of the United States except the irrigated districts, it probably produces serious damage most frequently in the Central States, between New York and Missouri, and in certain portions of Texas and California. In foreign countries this rust is especially common in northern Europe, and in certain seasons it is quite abundant also in Australia and Tasmania. According to Barclay (5. Vol. XXX, pp. 45–47), it is comparatively unimportant in India.

Wintering of the uredo.—Australia is the only country in which it has been demonstrated that the uredo winters over. Here, according to Cobb (19, p. 29), *P. graminis* lives the entire year in the uredo stage, either on self-sown grain or on certain native grasses, but whether he refers to one or to both of the forms of the rust on wheat and oats is not known. The writer has made a number of investigations to determine the question for this country, giving considerable time to the matter each winter, but has not yet been able to trace uredospores through the winter, although the form on oats has been found to live much longer than that on wheat.

Failing to find that the uredo winters over in Kansas, the writer thought that it might do so farther south, where the winters are milder, and that as spring advances the uredospores would be wafted northward from field to field and produce infection in their line of progress. In the hope of settling this point, therefore, he made a two-weeks' tour in December, 1895, through the State of Texas, from Indian Territory to the Mexican line. All the small grains except barley were closely examined in numerous fields around Fort Worth, Austin, Laredo, Houston, Beaumont, College Station, and McKinney, but it was rather surprising to find not only no trace of *Uredo graminis* either on wheat or winter oats, but also no *Uredo rubigo-vera* on wheat or rye. Winter oats was seen growing as far south as Laredo, but no trace of rust or of any other fungus could be found on any of the plants, although in examining old straw at several different places plenty of evidence was found that all the rusts of wheat and of oats were present during the preceding summer.

The latest date at which the writer observed the uredo on wheat Manhattan was August 27. A case observed as late as Septemt 19, supposed to be this rust, was afterwards found to be *Uredo rubi vera*. At Lincoln, Nebr., the uredo was found to be still active *Hordeum jubatum* as late as October 25, and if identical with the fo on *Elymus canadensis glaucifolius*, *Agropyron tenerum*, and *A. richa soni* it was found on these hosts at the same place as late as Novemt 16, 1897.

Liability of different varieties to this rust.—The series of experime for testing rust liability of wheat varieties made by McAlpine (51, 27, 28; 52, p. 26) in 1893 and 1894 and by Eriksson (31, pp. 333–341) 1890–93 are the only ones reported in which it was stated that *P. grami* was the chief species concerned. There is no means of knowing from t reports of any other experiments, whether in Australia or elsewhe which rust was most abundant or whether both were present. Howev in the reports of certain experiments, especially those conducted Maddox (50. pp. 8–23), it is frequently stated what part of the plant w affected, that is, whether the stem or the leaves. In such cases it m be inferred that both rusts were present, but as to which one predo nated only a guess, based on the comparative amounts of rust record on the leaves and stems, can be hazarded.

As already stated, this rust was present in the writer's experime at Salina and Manhattan, but appeared so late in the season that at t latter place no satisfactory estimate of the rustiness of different var ties could be made, and at the former, for the same reason, the rustin of spring varieties only could be graded. The following table shows t percentages of rust on the spring varieties:

TABLE 9.—*Comparative amount of Puccinia graminis on different varieties of spring wh at Salina, Kans., in 1896.*

Localities and names of varieties.	Bald or bearded.	Per cent of rustiness.
North Dakota:		
Glyndon 669	Bald	Traces.
Glyndon 673	do	Traces.
Glyndon 675	do	Traces.
Glyndon 747	do	Traces.
Glyndon 775	do	Traces.
McKissicks Fife	do	Traces.
Russia:		
Alsaco	do	10
Arnautka	Bearded	5
Byelokoloska	Bald	40
Byelokoloska (Kursk)	do	25
Chernokoloska	Bearded	10
Gharnovka	do	10
Ghirka	Bald	45
Ghirka (Samara)	do	30
Ghirka (Ekaterinoslav)	do	15
Imperial	Bearded	20
Krasnokoloska	Bald	15
Polish	Bearded	25
Saxonka	Bald	30
Siberia:		
Beloturka	Bearded	5
Byelaya		13
Chernokoloska		5 to 15
Kitaiska	Bearded	15

Localities and names of varieties.	Bald or bearded.	Per c of rustin
Siberia—Continued.		
Melka (Nerchinsk)	Bald	Trac
Australia:		
Blounts Gypsam	do	Trac
(Carre de Sicile Rouge x Hourblende) x Improved Fife.		Trac
14 x ([300 x Medeah] x 14).		Trac
Gypsum x (Improved Fife x Gypsum.)		Trac
Ladoa (=42 a x Ladoga)	Bald	
Pringles Defiance	do	Trac
Argentina:		
Bahia Blanca	Bearded	
Barletta	Bald	
Barletta (Santa Fe)	do	
Candeal Redondo		
Chubut	Bearded	
Chubut Spielart	do	
Entre Rios	do	Trac
Frances	Bald	
Russo		
Saldomé	Bearded	
Tusela	Bald	

As will be seen by comparing the figures in this table with those in ıble 3 for the same varieties and the same year, (1) all the varieties ›re as a rule more affected with the leaf rust than with the stem rust;) Polish, Gharnovka, and other varieties that are quite resistant to leaf st seemed to be about as badly affected with the stem rust as any of e others, while the North Dakota wheats and a few others that were dly affected with leaf rust were almost wholly free from stem rust; d (3) the Australian varieties, which were all sent in by Mr. Farrer, New South Wales, and which are supposed to be bred and selected th especial regard to resistance to this rust, performed their mission ıite well, all but Ladas showing only slight traces of the stem rust. nother fact of importance in regard to the durum wheats is that the em rust affected all portions of the plant except the seed. The bread ıeats were not so completely affected except in a few cases.

Pammel (55, pp. 498, 499) states that at the Iowa Agricultural Experiment Station, in 1892, when this rust "was very destructive," the

a. 1.—Healthy and shriveled grains of Jones Winter Fife harvested the same season in different parts of Kentucky.

llowing varieties were badly rusted: Velvet Chaff, Johnson, Early ed Clawson, Golden Cross, James White Fife, and Poole, while Turkh Red was, on the other hand, but slightly affected.

Farrer (33, p. 36) noted several years ago that the same varieties sist the two rusts in different degrees. Eriksson (31, pp. 340, 341; 27, 249) also found in his experiments that often those varieties most ısceptible to *P. glumarum* were most resistant to *P. graminis* and . *dispersa*. In Victoria in the season of 1893–94 McAlpine tried a ımber of varieties sent to him by Eriksson from Sweden, and the sults he obtained showed well the differences in susceptibility of the ıme varieties to different rusts. Though the varieties were recomended as being quite resistant to *P. glumarum* in Sweden, they were ıdly affected with *P. rubigo-vera* in Victoria. The matter was disıssed in detail by McAlpine before the Fourth Intercolonial Rust-in-Wheat Conference of Australia (52, p. 27), and also by Eriksson in an

article in *Zeitschrift für Pflanzenkrankheiten* (23, pp. 141–144). However, in many cases where one rust is always present the differences noted in resistance of the same variety to different rusts may be, in great part, more apparent than real. If one rust attacks certain varieties severely, another one, the conditions being the same, will naturally work most on those varieties where there is least competition, while if the former rust were not present at all or present only in small quantities the latter might affect other varieties as much.

Damage.—The damage to wheat from this rust has, perhaps, been sufficiently discussed already under orange leaf rust of wheat, hence suffice it to repeat here that it is the destructive wheat rust of the United States. The damaging effects of this rust in Kentucky are shown in fig. 1. Such effects seem to be of common occurrence in the State.

BLACK STEM RUST OF RYE.

(*Puccinia graminis secalis* Eriks. and Henn.).

It has not yet been determined whether there is a distinct form of *P. graminis* on rye in this country.[1] True, there are in different herbariums in the United States various specimens of rust on rye collected here and labeled *P. graminis*, but many of these identifications are known to be wrong, and as the writer has no practical experience with such a rust either in the greenhouse or in the field, he can as yet make no definite statements in regard to it. In a few experiments, however, he made successful infections on rye and barley, but not on wheat, with what seemed to be uredospores of *P. graminis* from *Hordeum jubatum*. These experiments, as already mentioned, seem to show that *H. jubatum* supports two distinct forms of *P. graminis*, but there is yet quite a possibility of error because the number of experiments was small.

BLACK STEM RUST OF OATS.

(*Puccinia graminis avenæ* Eriks. and Henn.).

Physiological relations.—The apparent differences between this rust and the form on wheat have already been discussed. Besides these differences it has occasionally been seen in cases of adjoining fields of wheat and of oats that one of the cereals was affected with the stem rust while the other remained entirely free from it. The writer has made more inoculation experiments with this rust than with any other, the work having been inaugurated about the same time as that with *P. coronata*. The results of the experiments are presented in the following table:

[1] Further observations and facts that have come to hand very recently make it certain that black stem rust occurs on rye, but whether it is identical with the form on wheat and barley is yet to be determined.

TABLE 10.—*Inoculation experiments with Uredo graminis avenæ.*

Date of inoculation.	Place where experiments were made.	Origin of inoculating material.	Plant inoculated.	Period of incubation (days).	Result.
1896.					
Feb. 6	Washington, D. C.	Oats	Siberian oats	7	Successful.
Do.	do	do	Black Tartarian oats	7	Do.
Feb. 14	do	do	Siberian oats	11	Do.
Do	do	do	Black Tartarian oats	11	Do.
Do	do	do	Early Para wheat	11	Negative.
Do.	do	do	Siberian wheat	11	Do.
Do.	do	do	Siberian barley	11	Do.
Do.	do	do	Siberian rye	11	Do.
Do.	do	do	Nebraska White Prize corn	11	Do.
Feb. 17	do	do	*Hordeum murinum*	10	Successful.
Feb. 19	do	do	Pied de Mouche oats	8	Do.
Do.	do	do	Imperial wheat	8	Negative.
Feb. 20	do	do	Amurskii oats	8	Successful.
Do.	do	do	Dun oats	8	Do.
Feb. 24	do	do	Nackter Kleiner Fahnen oats	9	Do.
Feb. 25	do	do	Black Tartarian oats	9	Do.
Mar. 4	do	do	Persian Black barley	15	Negative.
Do	do	do	Persian Red Spring wheat	15	Do.
Do	do	do	Spring rye	15	Do.
Do.	do	do	Frances wheat	21	Do.
Do.	do	do	*Imperial* wheat	21	Do.
Do	do	do	Japanese wheat No. 1	21	Do.
Do.	do	do	Dur de Volos wheat	21	Do.
Do.	do	do	*Corn*	21	Do.
Do.	do	do	Sugar cane	21	Do.
Do	do	do	Imperial wheat	10	Do.
Do.	do	do	Byelokoloska wheat	18	Do.
Do.	do	do	Crimean wheat	18	Do.
Do.	do	do	Siberian wheat	12	Do.
Do.	do	do	Chinese barley	18	Do.
Do.	do	do	*Triticum spelta amyleum*	18	Do.
Do.	do	do	Saldomé wheat	18	Do.
Do	do	do	Einkorn	18	Do.
Do	do	do	Kathia wheat	18	Do.
Do.	do	do	Banatka wheat	18	Do.
Do.	do	do	Safeed wheat	14	Do.
Do.	do	do	Varesotto wheat	14	Do.
Do.	do	do	Australian Glory wheat	14	Do.
Do.	do	do	Lal wheat	14	Do.
Do.	do	do	*Elymus sp. indet*	14	Do.
Do.	do	do	Corn	34	Do.
Do.	do	do	Siberian rye	34	Do.
Do	do	do	Siberian barley	34	Do.
Do.	do	do	Siberian wheat	34	Do.
Do.	do	do	Early Para wheat	34	Do.
Do.	do	do	Siberian rye	20	Do.
Do.	do	do	Siberian wheat	20	Do.
Do.	do	do	Siberian barley	20	Do.
Do.	do	do	Early Para wheat	20	Do.
Do	do	do	Corn	20	Do.
Do.	do	do	do	12	Do.
Do.	do	do	Siberian millet	14	Do.
Do.	do	do	Muzaffarnagar wheat	14	Do.
Do.	do	do	Shirosawa wheat	14	Do.
Mar. 11	do	do	*Avena fatua*	7	Successful.
Mar. 12	do	do	Siberian millet	12	Negative.
Do.	do	do	Safeed wheat	14	Do.
Do.	do	do	Haffkani wheat	12	Do.
Do.	do	do	Etampes oats	12	Do.
Do.	do	do	Nebraska White Prize corn	12	Do.
Do.	do	do	Persian Black barley	12	Do.
Mar. 13	do	do	*Dactylis glomerata*	9	Successful.
Mar. 18	do	do	Tardiva Danese oats	9	Do.
Mar. 19	do	do	*Dactylis glomerata*	10	Do.
Mar. 21	do	do	*Agrostis alba vulgaris*	12	Negative.
Do.	do	do	*Elymus virginicus*	12	Do.
Do.	do	do	*Phleum pratense*	12	Do.
Do.	do	do	*Triticum villosum*	12	Do.
Mar. 23	do	do	*Hordeum murinum*	9	Successful.
Mar. 26	do	do	*Triticum villosum*	17	Only one or two spots.
Mar. 28	do	do	*Hordeum murinum*	10	Successful.
Mar. 30	do	do	do	9	Do.
Do.	do	do	Amurskii oats	9	Do.
Do.	do	do	Shirosawa wheat	9	Negative.
Apr. 2	do	do	*Dactylis glomerata*		Successful.
Apr. 6	do	do	*Avena pratensis*	10	Do.
Do.	do	do	*Koeleria cristata*	10	Do.
Do.	do	do	*Phleum pratense*	14	Negative.

TABLE 10.—*Inoculation experiments with Uredo graminis avenæ*—Continued.

Date of inoculation.	Place where experiments were made.	Origin of inoculating material.	Plant inoculated.	Period of incubation (days).	Result.
1896.					
Apr. 9	Washington, D. C	Oats	Fentons Rust Proof oats	10	Successful.
Do	do	do	*Lolium perenne*	10	Negative.
Do	do	do	*Arrhenatherum elatius*	10	Successful.
Do	do	do	*Hordeum jubatum*	10	Negative.
Do	do	do	*Bromus unioloides*	10	Only one or two spots.
Do	do	do	*Avena pratensis*	10	Successful.
Do	do	do	*Agrostis alba vulgaris*	10	Negative.
Apr. 13	do	do	*Phleum pratense*	14	Only one or two spots.
Apr. 14	do	do	*Lolium perenne*	15	Do.
Apr. 17	do	do	*Hordeum murinum*	11	Successful.
Do	do	do	*Dactylis glomerata*	11	Do.
Do	do	do	Shirosawa wheat	11	Negative.
Do	do	do	*Trisetum subspicatum*	8	Successful.
Do	do	do	*Alopecurus alpestris*	8	Do.
Do	do	do	*Holcus mollis*	8	Do
Do	do	do	*Agrostis scabra*	8	Do.
Do	do	do	Fentons Rust-Proof oats	8	Do.
Do	do	do	*Polypogon monspeliensis*	8	Do.
Do	do	do	*Festuca sp. indet*	8	Do.
Do	do	do	*Eatonia sp. indet*	8	Do.
Apr. 23	do	do	*Brizopyron siculum*	13	Negative.
Do	do	do	*Sporobolus asper*	13	Do.
Do	do	do	*Poa pratensis*	13	Do.
Do	do	do	*Andropogon halapense*	13	Do.
Do	do	do	*Phalaris arundinacea*	13	Do.
Do	do	do	*Anthoxanthum odoratum*	13	Do.
May 1	do	do	Ligowo oats	14	Successful
Do	do	do	*Triticum spelta æstivum*	14	Negative.
Do	do	do	*Sporobolus cryptandrus*	14	Do.
Do	do	do	*Panicum crus galli*	14	Do.
Do	do	do	*Hordeum murinum*	13	Only one or two spots.
Do	do	do	Australian Glory wheat	13	Negative.
Do	do	do	*Kœleria cristata*	13	Do.
May 6	do	do	*Ammophila arenaria*	12	Successful.
May 7	do	do	Dun oats	15	Do.
Do	do	do	*Avena sterilis*	15	Do.
Do	do	do	*Phleum asperum*	15	Do.
Do	do	do	*Ammophila arenaria*	15	Do.
Do	do	do	*Eatonia dudleyi*	15	Negative.
Do	do	do	*Panicum crus-galli*	15	Do.
Do	do	do	*Poa annua*	15	Do.
Do	do	do	*Brachypodium distachys*	15	Do.
Do	do	do	*Sporobolus cryptandrus*	15	Do.
Do	do	do	*Eleusine egyptiaca*	15	Do.
Do	do	do	*Bouteloua curtipendula*	15	Do.
Do	do	do	*Eragrostis purshii*	15	Do.
Do	do	do	*Schedonnardus paniculatus*	15	Do.
May 20	do	do	*Triodia cuprea*	12	Do.
May 27	do	do	Oats	7	Successful
Do	do	do	do	7	Do.
Do	do	do	Barley	7	Negative.
Do	do	do	Rye	7	Do.
Do	do	do	Wheat	7	Do.
Dec. 21	do	do	Oats	10	Successful.
Do	do	do	do	9	Do.
1897.					
Feb. 24	do	do	*Avena pratensis*	13	Do.
Do	do	do	*Avena hookeri*	13	Do.
Do	do	do	*Dactylis glomerata*	13	Do.
Do	do	do	*Eatonia obtusata*	13	Do.
Do	do	do	*Bromus ciliatus*	13	Do.
Do	do	do	*Triticum villosum*	13	Negative.
Do	do	do	*Hordeum nodosum*	13	Do.
Mar. 30	do	do	*Avena fatua*	12	Successful.
Do	do	do	*Festuca ovina*	12	Negative.
Do	do	do	*Festuca arundinacea*	12	Do.
Do	do	do	Oats	12	Successful.
Do	do	do	*Festuca rubra glaucescens*	12	Negative.
Do	do	do	*Festuca gigantea*	12	Do.
Aug. 23	Stillwater, Okla	*Dactylis glomerata.*	Wheat	13	Do.
Do	do	do	Oats	13	Do.
Sept. 7	Manhattan, Kans	do	Wheat	8	Do.

TABLE 10.—*Inoculation experiments with Uredo graminis avenæ*—Continued.

Date of inoculation.	Place where experiments were made.	Origin of inoculating material.	Plant inoculated	Period of incubation (days).	Result.
1897. Sept. 7	Manhattan, Kans	*Dactylis glomerata.*	Oats	8	Successful.
Do	do	do	*Dactylis glomerata*	8	Do.
Dec. 23	Lincoln, Nebr	*Arrhenatherum elatius.*	Oats	12	Do
Do	do	do	Rye	12	Negative
1898. Jan. 5	do	Oats	Oats	21	Successful.
Do	do	do	Wheat	21	Negative.
Jan. 26	do	do	Oats	12	Only one or two spots
Do	do	do	Wheat	12	Negative.
Do	do	do	Oats	9	Successful.

Inoculations with this rust were successful on a greater number of hosts than inoculations with any other rust. Of course, as in the case of *Uredo coronata*, some of the experiments might not have proved successful with older plants, but nevertheless a number of inoculations on older plants also produced infections. On the other hand, in the case of Etampes oats, under date of March 12, 1896, and in a few other cases, the plants were inoculated just after germination upon damp cotton, but evidently were too young to be affected, the germ threads of the spores having ceased to grow before the first leaf was accessible.

An interesting feature of these experiments is the number of infected plants that belong to species of allied genera or to species that are rather similar in structure, and their close correspondence with those infected with *Uredo coronata*, as shown in Table 6.

The first forage grass proved to be a host for this rust in this country was *Dactylis glomerata*. On account of its susceptibility to infection, both when young and in an advanced stage, the writer for some time believed it to be a host for this rust. On August 2, 1897, both uredospores and teleutospores of the rust were found in great abundance on this grass on the grounds of the agricultural college at Stillwater, Okla.[1] A rusted plant was transferred from these grounds to the greenhouse of the Agricultural College at Manhattan, Kans. Material from this plant easily infected other plants of orchard grass and oats, producing sori on oats more vigorous than those from material of the same rust taken from oats. The rust was found on *Arrhenatherum elatius* at Lincoln November 16, 1897, and the reverse infections on oats from this material were produced December 23, 1897.

On the basis of experiments and observations made so far the following may be named as well-established hosts for the black stem rust of

[1] He had, of course, seen the rust on orchard grass several times before, as it is rather common, but had always supposed it to be equivalent to the form on wheat

oats: *Avena sativa patula*, *A. sativa orientalis*, and *A. sativa nuda*—cu vated varieties, and *Dactylis glomerata*, and *Arrhenatherum elatius*. T following species may at present be considered as probable hosts: *Av fatua*, *A. hookeri*, *A. pratensis*, *A. sterilis*, *Koeleria cristata*, and *Loli perenne*.

Occurrence and distribution.—The black stem rust of oats is certai more common than the black stem rust of wheat, owing probably to t fact that oats matures later than wheat and the stem rusts occur la than the other rusts. However, it is not known whether the stem ru of oats is generally commoner than the crown rust, although defini statements on this point might be made in the case of certain localities locality apparently being an important feature in this connection.

As in the case of stem rust of wheat, this rust is not constant occurrence, although perhaps more so than the former. Reports in cate that in the Southern States it is neither so common as it is in t Northern States nor so common as the crown rust. No trace of it w seen in Maryland during two successive seasons of observations by t writer. His examination of old straw at the Texas Agricultural C lege in December, 1895, showed that the crown rust was quite abunda the preceding summer, but none of the stem rust was observed.

Wherever oats is grown in foreign countries the distribution of t stem rust of oats seems to be quite general, but in some regions it said to be of little economic importance.

Wintering of the uredo.—So far as yet known, this rust does not wi ter its uredo in this country. The following table gives a summary the writer's observations of the occurrence of the uredo in late summ and autumn:

TABLE 11.—*Summary of observations on late occurrence of Uredo graminis avenæ.*

Host plant	Date of observation.	Place of observation.
Oats	Sept. 17, 1896	Manhattan, Kans.
Do	Nov. 2, 1896	Do.
Do	Aug. 27, 1897	Do.
Dactylis glomerata	Aug. 23, 1897	Stillwater, Okla.
Do	Oct. 8, 1897	Do.
Oats	Oct. 12, 1897	Payne County, Okla.
Dactylis glomerata	Nov. 12, 1897	Manhattan, Kans.
Oats	Nov. 14, 1897	Lincoln, Nebr.
Arrhenatherum elatius.	Nov. 16, 1897	Do.

The fact that the uredo was found on other hosts than oats, and esp cially the fact that these hosts are perennial, strengthens the probabili that the uredo winters over, but at the same time weakens the prob bility that it winters on oats. At any rate, it is easily seen that orcha grass and tall meadow oat grass are not likely to prove desirab neighbors for the oat field.

As already stated, Cobb (19, p. 29) mentions that *P. graminis* winte over in the uredo stage in Australia, but he is not sufficiently explic to justify the conclusion that he includes this form on oats.

Liability of different varieties to this rust.—But little information exists as to the liability of different varieties of oats to rust in this country based on any case in which it was definitely known that the stem rust was the chief one under observation. In the season of 1894 the writer assisted Prof. J. H. Shepperd in grading the rustiness of varieties of oats grown at the North Dakota Agricultural Experiment Station, *P. graminis* being the dominant rust on oats that season, not only there but also throughout the North and West. The following season Prof. H. L. Bolley, of that station, graded the rustiness of the same varieties, and in a recent letter received from him he states that *P. graminis* was the chief rust present that year, but that the presence of *P. coronata* accounts for the small percentages of rust noted for certain varieties. The results of the two years' grading were reported by Professor Shepperd in a bulletin issued March, 1896 (64, pp. 38–40). The percentages for the same varieties for the two seasons correspond quite well as a rule, and show almost entire freedom from rust in the case of Early White Russian, Fentons Rust Proof, Tartarian, and Great Northern, and an abundance of rust on Giant Yellow, American White, Badger Queen, and North Star.

This rust occurred to a small extent on the varieties of oats in the field experiments at Salina, but on account of its late appearance and the great abundance of the crown rust it was impracticable to grade the amounts on the different varieties.

In Australia, where so much has been written on rust-resistant wheats, apparently no attention has been given to rust-resistant oats, probably for the reason that oat rust is of little economic importance in that country. In 1893 Eriksson made some observations (31, pp. 348–350) on rust liability of varieties of oats in Sweden, especially as regards the black stem rust, and concluded that in Sweden there is no particular difference in the susceptibility of different sorts of oats to this rust.

Damage.—The damage which this rust causes to oats in this country is even greater than that produced by the form occurring on wheat. In fact almost every year thousands of acres are totally destroyed in some portions of the country by this parasite, the damage being greatest north of the thirty-seventh degree of north latitude and east of the ninety-fifth degree of west longitude. According to Eriksson (31, p. 386), it is also very destructive at times in Sweden, the damage to oats in that country from this cause in 1889 amounting to 16 million crowns (about 4½ million dollars).

MAIZE RUST.

(*Puccinia sorghi* Schw.).

Physiological relations.—The fact that the maize rust bears some morphological resemblance to the rusts of certain grasses, particularly to *P. graminis* of wheat and oats, led the writer to suspect that it migh

be equivalent to one or more of these, and it was for this reason especially that in the inoculation experiments with the rusts of the other four cereals Indian corn was employed several times, as were also other grasses. A few experiments were also made with the uredo of maize rust itself. The following results were obtained:

TABLE 12.—*Inoculation experiments with Uredo sorghi.*

Date of inoculation.	Place where experiments were made.	Origin of inoculating material.	Plants inoculated.	Period of incubation (days).	Result.
1896.					
Sept. 17	Manhattan, Kans	Corn	Corn	5	Successful.
Sept. 21	do	do	do	7	Do.
Dec. 22	Washington, D. C	do	do	7	Do.
1897.					
Apr. 10	do	do	*Euchlæna mexicana*	11	Do.
Oct. 14	Manhattan, Kans	*Euchlæna mexicana.*	Corn	11	Do.

The time of incubation for this uredo is shorter than that of any other cereal rust, varying from five to eight days, under ordinary greenhouse conditions.

Until recently it was not known that maize rust occurred on any host in this country except Indian corn. In pursuance of an idea long entertained that teosinte (*Euchlæna mexicana*), on account of its close relation to corn, might also be a host for the maize rust, the writer planted some teosinte seed (obtained from the Division of Agrostology, which kindly supplied seeds of various grasses used in the writer's experiments) in the greenhouse in the spring of 1897, and successfully inoculated the resulting plants, a longer period of incubation being required, however, than in the case of corn. On August 21, 1897, he found both the uredo and teleuto stages on teosinte growing on the grounds of the Agricultural College at Stillwater, Okla., and later successfully inoculated corn with uredospores from the teosinte, vigorous sori being produced.

It is a curious fact that while inoculations with this rust resulted in adding another host for it, similar experiments with the other cereal rusts have shown that the number of their hosts is much smaller than had been supposed. The established hosts for this rust in the United States, as determined by experiments so far made, are *Zea mays* (cultivated varieties of the groups *saccharata*, *dentiformis*, and *vulgaris*) and *Euchlæna mexicana*.

Occurrence and distribution.—Maize rust occurs in all parts of the United States where the ordinary varieties of field corn, sugar corn, and pop corn are grown, but it is rarely found in great abundance in any locality. It attains its maximum abundance on ordinary field crops about October 1, or about three months later than any other rust of cereals. Whether the introduction of teosinte as a forage crop will have any effect in facilitating the spread of the rust remains to be seen.

This rust is also reported from South America, Germany, France, Italy, Portugal, India, and south Africa; but owing to the facts that the genus Sorghum is included with its hosts and that Barclay has shown (5, Vol. XXVIII, pp. 257–259; 3, pp. 214, 215) that the rust on *Sorghum vulgare* in India is a distinct species, which he called *P. penniseti*, it is questionable whether it actually occurs in all these countries.

Wintering of the uredo.—This rust is not yet known to winter its uredo in any country, and as no æcidial stage has been discovered, the manner of its perpetuation throughout the year is entirely unknown.

Liability of different varieties to this rust.—There is as yet no difference known in the susceptibility of different varieties of corn to this rust, but so far no investigations have been made to determine this point. The rust seems to be of but little economic importance.

Damage.—The writer has occasionally seen patches of very late corn injured by this rust. If corn is sown broadcast as a forage crop late in the season it is likely to be badly damaged, but as a rule the rust does little or no damage. Pammel mentions (56a, p. 854) that in Iowa the yield of corn, especially of sweet corn, is sometimes materially lessened because of rust.

GENERAL REMARKS.

Many inoculation, germination, and other physiological experiments not mentioned in this bulletin but bearing closely on the cereal rust problem, will be discussed in other publications of this Division. These experiments, like those made by Eriksson, show that in addition to the forms herein described, the cereal rusts have also distinct specialized forms on various grasses, but as these forms do not occur on the cereals they are usually of no economic importance. In addition to the experiments already reported in a former publication (15, pp. 448–452), numerous others were made by the writer to determine the behavior of the uredospores from a chemical standpoint. Also hundreds of inoculations on cereals with the æcidia of various plants other than barberry have been made for the purpose of discovering, if possible, other æcidial hosts for the cereal rusts, but so far none have been found. Again, the morphological differences between the different forms of the cereal rusts are, in a few cases at least, of considerable importance, but it is thought best, under the circumstances, to discuss them in another publication.

Something should be said concerning the value of the inoculation experiments reported in this bulletin. It may be claimed by some that the experiments which proved successful in the greenhouse and on young plants would probably result negatively in a greater number of cases if made out of doors on more mature plants. This is not only possible, but, as already shown, the writer's results make it very probable; and thereby the experiments are all the more valuable, as in the greenhouse they are more exclusive in nature and in no case is an infection likely to take place out of doors if it can not be produced in

the greenhouse. In case there is an error, therefore, it is on the safe side, and the number of possible host plants is gradually more and more limited, until finally, by reverse infections, the actual host plants are established. As already stated, a number of instances of repeated experiments on older plants resulted negatively, although they had been successful in the first experiments.

The "mycoplasmatic" theory, advanced by Eriksson (25, pp. 475–477) to explain the manner of perpetuation of *Puccinia glumarum* from one season to another, has already been mentioned. A description of Eriksson's experiments with this rust seems to reveal conditions different from those existing in the case of any other cereal rust. Barley plants grown from the seed and completely shut off from external influences showed rust after a time. The seed was sown in sterilized soil and grown in glass houses, into which air could pass only through cotton-wool filters. From other statements and illustrations in *Die Getreideroste*, it seems probable that we have here at last an instance of the propagation of grain rust through the medium of the germinating seed of the host, as in some of the smuts. Eriksson claims that, as he found no mycelium present, the rust exists in the form of a mycoplasma in the cells of the embryo in a latent symbiotic state during the interval between harvest and seeding time. As the rust in question does not exist in this country, the writer has had no opportunity to investigate the matter. No other cereal rust is known to live within the seed in any form or manner.[1]

SUMMARY.

(1) At least six and probably seven distinct rusts affect the cereals of the United States. They are as follows: Orange leaf rust of wheat (*Puccinia rubigo-vera tritici*), orange leaf rust of rye (*P. rubigo-vera secalis*), crown rust of oats (*P. coronata* Corda), black stem rust of wheat and barley (*P. graminis tritici* Eriks. and Henn.), black stem rust of rye (*P. graminis secalis* Eriks. and Henn.), black stem rust of oats (*P. graminis avenæ* Eriks. and Henn.), and maize rust (*P. sorghi* Schw.).

(2) Though all these rusts except that on maize probably cause some injury occasionally, the black stem rusts of wheat and of oats are by far the most destructive.

(3) All the rusts are pretty evenly distributed over the United States, wherever their respective hosts are grown, except the stem rusts, which are perhaps most prevalent in the region between the Alleghanies and the ninety-fifth degree of west longitude north of the

[1] Cases where rusts other than those of cereals live over in the seed are not, however, unknown. The actual peridia of the æcidium of *Uromyces euphorbiæ* C. and P. may often be seen within the seed of *Euphorbia dentata*. The writer's investigations concerning this rust are yet to be published. In 1890 Ralph (61, p. 18) also described an æcidium affecting the seed of *Senecio vulgaris* in Australia, which seems to furnish one other instance.

thirty-seventh degree of north latitude and in portions of Texas and California. The leaf rusts and the crown rust are proportionally more important in the Atlantic and the Southern coast States.

(4) The damage to wheat and oats from rust in this country probably exceeds that caused by any other fungous or insect pest, and in some localities is greater than that caused by all other enemies combined.

(5) As yet there is but little certainty concerning rust resistance, which varies continually under different conditions. Heretofore in testing varieties for rust resistance, little attention has been paid to the species of rust concerned.

(6) The following hardy prolific varieties of wheat can usually be depended upon to resist orange leaf rust to a considerable degree: Turkey, Mennonite, Odessa, Rieti, Pringles No. 5, and Pringles Defiance, and for early spring sowing Haynes Blue Stem and Saskatchewan Fife. Some of these varieties may be resistant to the black stem rust also, but this has not been definitely determined.

(7) The following varieties also resist leaf rust, probably in nearly all cases: Theiss, Fulcaster, Oregon Club, Deitz Longberry, Sonora, Diehl Mediterranean, Arnolds Hybrid, and California Spring.

(8) Durum and poulard wheats are very resistant to the leaf rust, but so far have been used chiefly in making macaroni. A few of the most important of these wheats are, Arnautka, Taganrog, Beloturka, Medeah, Gallands Hybrid, Petanielle Noire de Nice, Cherunska, Cretan, Missogen, and Nicaragua.

(9) During two years when rust was very severe Einkorn, a variety of *Triticum monococcum*, used for stock feed, remained absolutely proof against the leaf rust.

(10) So far as known, any ordinary variety of wheat may rust badly if sown late, but the following, although susceptible to rust, may sometimes escape it because of early maturity: Early May, Zimmerman, Early Baart, Allora Spring, Roseworthy, Yemide, Kathia, Canning Downs, and Japanese No. 2. However, four of these—Early Baart, Allora Spring, Roseworthy, and Canning Downs—are probably not sufficiently hardy for northern latitudes.

(11) Of the varieties of oats, Texas Rust Proof is commonly considered rust resistant in the Southern States, but to which of the rusts is not known. In the Northern States the varieties more or less resistant to black stem rust are Early White Russian, Great Northern, Tartarian, and Fentons Rust Proof.

(12) Experiments so far made with uredospores show that the orange leaf rusts of wheat and rye do not transfer to hosts outside of the genera Triticum and Secale, respectively, but that, on the other hand, their uredo stages winter over readily in this country, beginning first on self-sown grain and probably later transferring to the regular fall-sown crop. **All farms should therefore be kept constantly and rigidly free of volunteer wheat and rye.**

(13) The crown rust of oats is not yet known to winter its uredo nc to transfer to any other hosts than species of Avena.[1]

(14) The black stem rust of wheat occurs also on barley and *Hordeu jubatum*. So far as known it does not winter its uredo in this countr

(15) It has not yet been definitely determined whether there is a di tinct form of the black stem rust on rye in this country, but it is ver probable that there is.

(16) The uredo of the black stem rust of oats is not yet known t winter in the United States, but it has been found alive very late i the autumn. The rust, however, is also common on the two grasse *Dactylis glomerata* and *Arrhenatherum elatius*, hence oats may be easil infected with it when grown in close proximity to these grasses.

(17) Maize rust occurs also on teosinte in this country, but does no winter its uredo. It is of little economic importance.

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[1] As already mentioned, later experiments show that the æcidium of *Rhamnu lanceolata* infects oats, *Phalaris caroliniana, and Arrhenatherum elatius.*

[2] Since this bulletin was prepared Dr. H. Klebahn has published in Zeitschr. für Pflanzenkrank., Feb. 4, 1899, Bd. VIII, Heft 6. pp. 321-342, a lengthy article entitled "Ein Beitrag zur Getreiderostfrage." It consists chiefly in an account of experiments made with the different grain rusts, and of the results, which seem to conflict more or less with those obtained by Eriksson. In Centralbl. f. Bakt., Parasit., u. Infekt., Dec. 19, 30, and 31, 1898, Abt. II, Bd. IV, pp. 855-859, 887-896, 913-91 (6 illus.) appears an article by Prof. H. L. Bolley, entitled "Einige Bemerkunge über die symbiotische Mykoplasmatheorie bei dem Getreiderost," in which the author, on the basis of his own experiments, also criticises Eriksson's theory, an gives the results of other investigations, which show the great vitality of uredospores and æcidiospores and the possibility of uredospore germ tubes passing through the actual epidermis of the leaf as well as the stomata. The original of this paper (in English) was presented before the Boston meeting of the American Association for the Advancement of Science, August, 1898.

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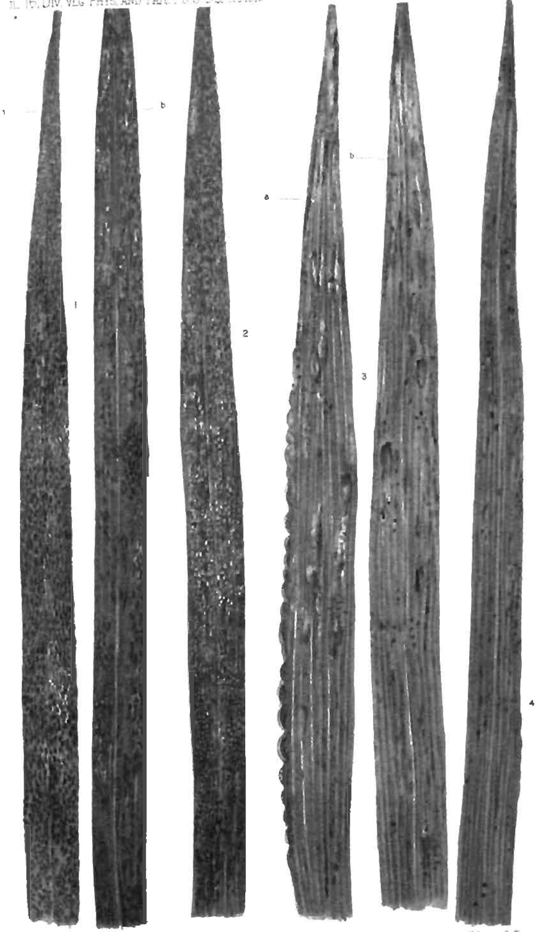
EXPLANATION OF PLATES.

PLATE I.—Comparative rustiness of four varieties of wheat from *Uredo rubigo-vera tritici*, Garrett Park, Md. *1* Buckeye: *a* lower surface of leaf, *b* upper surface of leaf; *2* Golden Prolific; *3* Gallands Hybrid: *a* lower surface of leaf, *b* upper surface of leaf; *4* Beloturka. The brown spots on *3* and *4* were not caused by rust.

PLATE II.—Yx and Theiss wheats rusted with *Puccinia graminis tritici* and *P. rubigo-vera tritici* at Manhattan, Kans. *5* uredo of *P. graminis; 6* uredo and teleuto stages of *P. graminis; 7* teleuto stage of *P. graminis; 8* uredo and teleuto stages of *P. rubigo-vera; 9* teleuto stage of *P. rubigo-vera.*

PLATE III.—Cereal rusts produced by artificial infection on young plants. *10 Uredo rubigo-vera secalis* on rye; *11 U. rubigo-vera secalis* on rye, showing how the chlorophyll remains about rust spots during changes of the coloring matter; *12 U. rubigo-vera secalis* on *Secale montanum; 13 U. rubigo-vera tritici* on wheat; *14 U. coronata* on oats.

PLATE IV.—Cereal rusts produced by artificial infections on young plants. *15 Uredo coronata* (*a*) and *U. graminis avenæ* (*b*) produced on the same leaf of oats; *16 U. graminis avenæ* on oats; *17 U. graminis avenæ* on *Kœleria cristata; 18 U. graminis tritici* on Taganrog wheat; *19 U. graminis* on the leaf of barley; *20 U. graminis* on the sheath of barley; *21 U. sorghi* on corn leaf; *22 U. sorghi* on corn, but with teleuto stage also.



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Comparative Resistance of four varieties of wheat from Orange Leaf Rust.

Yr and Theiss Wheats Rusted in 1897.

Heliotype Co, Boston

Helitype Co., Bos.

Cereal Rusts from Artificial Infections.

Cereal Rusts from Artificial Infections.

Heliotype Co. Boston.